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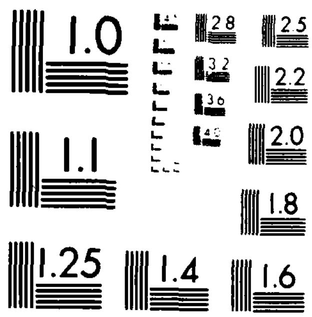
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AN EVALUATION OF ALTERNATIVES
FOR PROCESSING OF
ADMINISTRATIVE PAY VOUCHERS:
A SIMULATION APPROACH

Charles B. Venable, Captain, USAF
Lawrence E. Zebell, Captain, USAF

LSSR 61-82

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Management in the 2750th Air Base Wing's Accounting and Finance Office (ACF) has devised a Point System for use in determining the productivity of the ACF Travel Section (ACFTT). This Point System sets values (.5 to 5+) to be assigned to incoming travel vouchers based on voucher complexity. This research had set objectives of (1) building an ACFTT model that uses the Point System to simulate travel voucher processing, (2) using the model to project ACFTT personnel requirements. The built model was verified but not validated. The hypothesized reason it was not is the existence of an informal feedback loop within ACFTT for which there was no data available. Further research is required to investigate this feedback loop and determine its full impact on the ACFTT system.

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AN EVALUATION OF ALTERNATIVES FOR PROCESSING OF ADMINISTRATIVE PAY VOUCHERS: A SIMULATION APPROACH

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirement for the

Degree of Master of Science in Logistics Management

By

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This thesis, written by

Captain Charles B. Venable

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Captain Lawrence E. Zebell

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

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Daniel B. Fox
COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

Overview

The filing of vouchers for payment of travel claims has been in practice by military members (uniformed and civilian) since funds were first set aside to support an army. Although a strict historical account of the evolution of methods used to pay travel claims has not been maintained, it is generally agreed that the first travel claims were simply receipts from merchants, innkeepers, blacksmiths, etc. that the military traveler collected during his official travels and submitted to the paymaster later for reimbursement (6). The early claims were relatively uncomplicated and straightforward. A paymaster had simply to determine what was just and fair and reimburse the traveler accordingly.

Such simplicity is no longer the rule. Within the Department of Defense (DOD) an Accounting and Finance Office (AFO) at each installation is responsible for seeing that not only travel, but any valid legal claims are paid. The travel and transportation allowances authorized DOD members are contained in the Joint Travel Regulations (JTR). Volume 1 of the JTR prescribes allowances authorized for uniformed members of DoD, and Volume 2 of the JTR is for civilian allowances (14:1-1). Should a situation arise that is not covered in the JTR and the local AFO cannot determine proper action, the situation can be forwarded through proper channels to the Comptroller General for a final decision. Such an action then sets policy for use in similar situations at other installations. In addition to the JTR, personnel must comply with respective services regulations and manuals. Within the Air Force, primary guidance is provided through Air Force Regulation 177-103. Other regulations offer secondary guidance. The volumes of regulations, procedures, comptroller decisions, etc. prompted one AFO to make a statement that might indicate a longing for less complexity when he said, "We have gone from just and fair to a highly complicated set of rules [7]."

At Wright-Patterson Air Force Base (W-P AFB) the functions concerning financial transaction are within the Accounting and Finance Office (ACF) in Building 1 under the command of the 2750th Air Base Wing (ABW). The processing of travel payments is handled by the Travel Section of ACF (ACFT). A branch ACFT office exists in Building 262, Headquarters, Air Force Logistics Command, but will not be considered a factor in this research. ACFT is not only responsible for the processing of travel vouchers, it is also responsible for entering the travel performed by the member into the accounting records and onto the member's individual travel record. These responsibilities are divided between two subsections of ACFT: Accounting (ACFTA) and Computation (ACFTT).

Within ACFTT the calculations are done on a travel voucher to determine the authorized reimbursement for a traveler. The complexity of figuring reimbursement for a travel dictates that the personnel performing the calculation be highly trained and knowledgeable of the various regulations. Vouchers must also be processed within three workdays of receipt (day of receipt plus two) so the process is further complicated.

ACF management often finds the task of obtaining and retaining qualified people to work in ACFTT a difficult one. The work of processing vouchers is hard and sometimes unrewarding, though the work environment itself was cited as being the best of its kind in the Air Force. The pleasant surroundings are often offset by the high volumes of incoming vouchers and shortage of people (7). Often in the past, the three-day standard has not been met because of the personnel and workload factors. This not only causes a violation of AFR 177-103, but creates customer/traveler dissatisfaction and increases the job pressures of ACFTT personnel.

One reason for lateness of voucher processing in the past was the absence of a procedure for tracking vouchers through ACFT. The vouchers were only hand marked with the Julian date (1 Jan = 001, 31 Dec = 365) and put into an in-basket to wait for processing, with no close monitoring of date-due-out of individual vouchers. With over 70,000 incoming vouchers a year, the ACF management recognized that a method had to be developed which would not only enable close monitoring of incoming vouchers to occur, but which would give a measure of output produced in some form other than number of vouchers processed.

The method developed was the Point System (2). Incoming vouchers are evaluated by an experienced supervisor according to complexity and each voucher is assigned a point value (.5 to 5+) based on that complexity. The vouchers are then marked with point value and Julian date and put into the to-be-processed basket. Each morning when the workday begins (0730 M-F), a work section leader pulls the vouchers which need processing first and assigns them to the personnel who will make the necessary calculations (computors). Once the vouchers are completed by the computors, they are given to the auditors for checking of accuracy. When the auditors are finished, the process cycle of the voucher is considered finished, and the voucher is sent to ACFTA for check processing and payment.

The Point System was devised based on the average time it takes an adequately trained computor or auditor to process a voucher. A computor should be able to process one point every fifteen minutes and an auditor should process two points in the same time. Thus, an output standard is set at four points per hour for a computor and eight points for an auditor. Under the Point System each worker keeps a daily record of productive time (processing vouchers) and non-productive time (filing, telephone, training, etc.) along with the number of points processed in the productive time available. Productive time available multiplied by the standard of 4 or 8 points an hour sets the number of points that person should have processed. When actual points processed are divided by the productive hours available, the worker's operating efficiency is determined. This gives management a method for tracking vouchers (counted daily and recorded) and for managing the available workforce (above or below standard) (2).

The Point System has helped ACF management to better manage available voucher workload and the available ACFTT workforce. But as an aid to projecting personnel requirements the Point System is rather limited. With 13 computors and 6 auditors assigned at the time of this thesis, a considerable amount of statistical data must be collected on vouchers (number and type), computors (productive time and compute speed), and auditors (productive time, compute and audit speed). This data then requires statistical analysis and tests to determine what figures are valid for projecting personnel requirements. ACF management can use an overall average of speeds and times, but this type of "back-of-the-envelope" modeling has obvious limitations.

A formal model that uses the Point System in simulating ACFTT voucher processing has been built (13). However, its emphasis on system stability prevents using it as a reliable indication of future personnel requirements. An average processing time for each group of auditors and computors is input into the model and that average is used in calculating processing time per voucher, regardless of who does the processing. Thus, if a person with an individual processing time higher or lower than the group average leaves the system, the impact of his departure is not accurately reflected. On-leave/non-productive and available-for-duty were input as having a full eight hours of productive time. In the real ACFTT system, some personnel may have less productive time than others, and those who are productive are occasionally non-productive for some part of the eight-hour duty day. Again, the loss of an individual not having times near the group average would have only an average impact on the model.

What is needed by ACF management is a model that will enable them to forecast with some level of confidence their ACFTT personnel requirements. The model should have the capability to reflect the individual processing speeds and productive times of those people working in the system. Manpower projections could then be made which would more accurately reflect the loss or gain of a given individual.

Statement of the Problem

The specific problem addressed by this thesis is: Can a model be developed that ACF management can use to project manpower requirements based on incoming vouchers and the point system?

Objectives

1. To construct a model of ACFTT that will use incoming vouchers as input and points and vouchers processed as output.

2. To determine the number of computors and auditors required to meet the three-day processing standard, given the voucher workload.

Research Questions

1. Can a model be developed which will accurately reflect the ACFTT workload, based on workforce and the

Point System?

2. If a model can be developed, can it by used by ACF management to project manpower requirements?

CHAPTER II

RESEARCH METHODOLOGY

Overview

Chapter I outlined a significant problem as identified by ACF management: how to project and validate workforce requirements for processing travel vouchers. Our stated objectives of research were to first build a model of the ACFTT system and next, to use the model to determine the number of personnel needed to meet the three-day voucher processing standard. Chapter II discusses the steps taken to build our ACFTT model. Included are our initial model and a brief overview of data requirements.

Modeling and Simulation

A model may be either a physical or conceptual representation of a "real" system.

> By a model of a "real" system we mean a representation of a group of objects or ideas in some form other than that of the entity itself, and here the term "real" is used in the sense of "in existence or capable of being brought into existence" [12:2].

A model can be designed in either descriptive or prescriptive form. A descriptive model serves to explain and acts as an aid to understanding the real system, while a prescriptive model duplicates or predicts the behavior of a real system.

> A prescriptive model useful in design is almost always descriptive of the entity being modeled, but a descriptive model is not necessarily useful for design purposes [12:7].

A real system model can also be used for training and instruction purposes and as an aid to thought, experimentation, and prediction (12:5).

Simulation is defined as:

> ...the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system [12:2].

Thus, we see that simulation can be considered to be a form of modeling and is useful for our purpose of developing a model which can be used to forecast manning requirements for ACFTT. In fact, the nature of a good simulation is that:

> (1) it is concerned with the operation of systems; (2) it is concerned with the solution of real world problems; (3) it is performed as a service for the benefit of those in control of the system [12:21].

Even though simulation "is concerned with the solution of real world problems", it does not provide a solution in the manner of analytical techniques. Rather, simulation allows the decision-maker the ability to compare and contrast the effects various strategies can have on the system without experimenting with and disrupting the real system (12:11). This obviously is a major advantage of simulation, which when coupled with its compression of time, offers the decision maker a powerful tool to use in analyzing complex real world systems.

In using simulation, one must remember that it is "not a panacea for all of management's problems [12:14]." In fact, simulation has several disadvantages, one of which is that "simulation can appear to reflect accurately the real world situation when, in truth, it does not [12:13]." Verification and validation help to reduce but not erase this disadvantage. Another disadvantage is that simulation is imprecise, and the degree of imprecision cannot be measured. "Analysis of the sensitivity of the model to changing parameter values can only partially overcome this difficulty [12:13]." Thus, with the advantages listed earlier and using the measures listed here as disadvantage reduction techniques, we concluded that simulation was the best method available for accomplishing our objective.

Having chosen simulation as the technique to be used in meeting our research objective, the next step is to outline the stages through which our work progressed. Shannon identified eleven steps that any simulation should follow. These steps are easy to understand and constitute the method taught here at the Air Force Institute of Technology (AFIT). These eleven steps, with a short description of each, are:

1. System Definition: Determining the boundaries, restrictions, and measure of effectiveness to be used in defining the system to be studied.

2. Model Formulation: Reduction or abstraction of the real system to a logic flow diagram.

3. Data Preparation: Identification of the data needed by the model, and their reduction to an appropriate form.

4. Model Translation: Description of the model in a language acceptable to the computer to be used.

5. Validation: Increasing to an acceptable level the confidence that an inference drawn from the model about the real system will be correct.

6. Strategic Planning: Design of an experiment that will yield the desired information.

7. Tactical Planning: Determination of how each of the test runs specified in the experimental design is to be executed.

8. Experimentation: Execution of the simulation to generate the desired data and to perform sensitivity analysis.

9. Interpretation: Drawing inferences from the data generated by the simulation.

10. Implementation: Putting the model and/or results to use.

11. Documentation: Recording the project activities and results as well as documenting the model and its use [12:23].

This chapter concerns itself with portions of the first four steps, plus step six. Chapter III concentrates on steps two, four, six, and eight, while Chapter IV examines step three in detail and highlights step five. Chapter V reports the outcome of steps five, seven, eight, and nine. Step ten must be left to ACF management, while this thesis represents step eleven.

System Definition

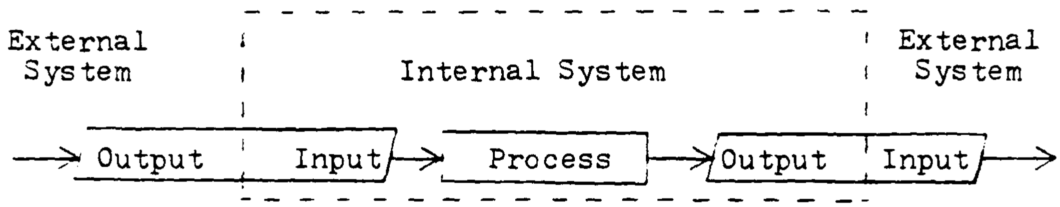
A key word appearing in modeling and simulation works and discussions is system. A system is here defined as:

> ...a set of objects together with relationships between the objects and between their attributes connected or related to each other and to their environment in such a manner as to form an entirety or whole [11:12]

Another, similar definition of a system is: "a group or set of objects united by some form of regular interaction or interdependence to perform a specific function [12:15]."

These definitions point out that a system has a set of objects which possess some interrelationship with the system and with their environment. The final point brought forth from these definitions is that the set of objects combine to complete some process. In fact, "the input to a system is the output of another system, and...the output of the system becomes the input to another system [11:12]." Figure 2-1 depicts this relationship.

Figure 2-1



Diagrammatical Input-Process-Output Representation

The broken line marking the separation of internal and external systems is used to represent the interaction between the system and its environment. This interaction takes place not only as stated, but also within the inputs to the process. The more control the environment exerts on the input, the less control the system has and the input becomes part of the environment. The reverse of this control makes the input a resource of the system (11:22-27). An example of this is the personnel of the Computation section. Unless the individuals are excused from duty or fired, they must report for work. Therefore, they are resources. Each person arrives with certain attributes, one of which is his processing speed. The system's internal environment, Muzak, and pleasant surroundings affect individual speed, but the external environment, such things as burnt toast and traffic jams, may also affect and contribute to a reduction of the individual's processing speed for that day. Consequently, there is an interaction between the environment and resources along with the environment and the system. An explanation of the system's boundary, together with the definition of a system, forms the Travel Computation System depicted in Figure 2-2.

Model Formulation

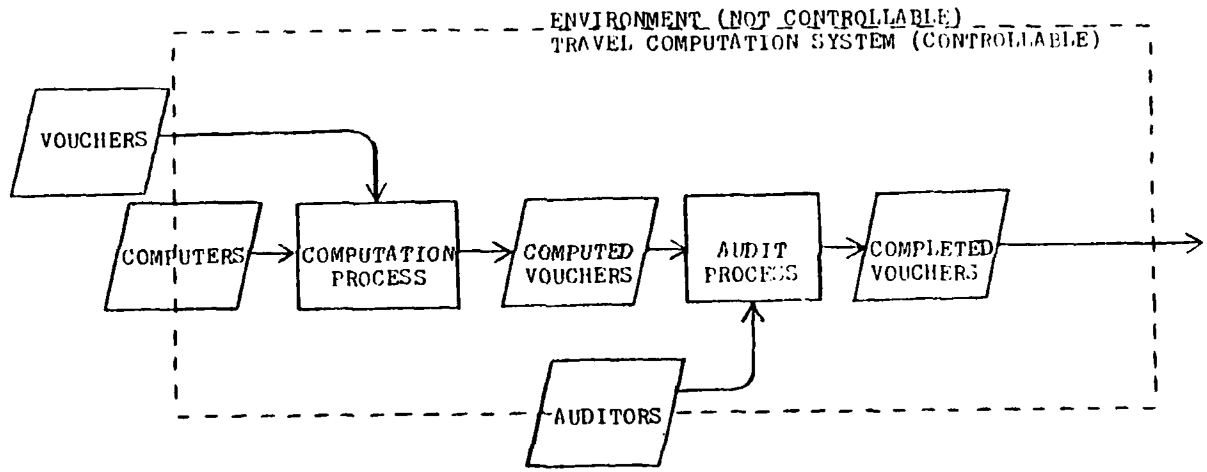
Pritsker contends that "the model building process should be considered as an iterative one [9:2]." He goes on to say that:

> Q-GERT (which stands for Queue-Graphical Evaluation and Review Technique) allows the user to easily modify or extend his model, and allows for hierarchical modeling. Thus, simple "first cut" models can be built quickly, and complex models can be built from these simple models [9:3].

We used this iterative process as we built our simulation model from the Travel Computation section system model, as shown is Figure 2-2, to our final Q-GERT model.

As stated, our final simulation model is coded in Q-GERT. This coding method was chosen because GERT "can be used to model projects consisting of sets of activities while Q-GERT augments GERT with the addition of queueing and decision capabilities [9:vii]." The voucher computation and audit processes are the set of activities allowing the use of GERT. The computation section, in an effort to complete all vouchers in the required time and to ensure an order to the process,

Figure 2-2



TRAVEL COMPUTATION SYSTEM

uses a First-In-First-Out (FIFO) queueing system, which allows the use of Q-GERT. A final reason for choosing Q-GERT was its availability for our use on the AFIT HARRIS computer system.

Q-GERT allowed us to easily follow the iterative process:

> ...Q-GERT supports a systems approach to problem resolution consisting of four steps. First, a system is decomposed into its significant elements. Second, the elements are analyzed and described. Third, the elements are integrated in a network model of the system. Fourth, system performance is assessed through the evaluation of the network model [9:vii].

The measures of the system which we were interested in were the combined waiting and service times, plus the reaction of the queue levels as we varied the personnel levels.

The Q-GERT language uses a series of nodes and branches. The nodes are used to model milestones, decision points, and queues, while branches represent activities or processes which are separated by the nodes. The vouchers represent transactions flowing through the Q-GERT network, while the computors and auditors represent the servers who perform the process.

Once the iterative process is completed, in the form of a Q-GERT program, the model must be verified. Verification ensures "that the model behaves the way an experimenter intends [12:30]." Verification of the model entailed ensuring the proper flow of transactions, the proper selection and use of mathematical equations, and, finally, checking the program logic. To ensure its accuracy, the program logic was reviewed by the Chief of the Travel Computation section. Once the verification was completed, the coded simulation model was loaded onto the HARRIS computer.

Data Requirements

The initial model developed (shown in Figure 2-2) identifies three inputs: the voucher, computors, and auditors. However, closer examination of each of these areas revealed the need for more than raw number collection.

When a voucher arrives at ACFTT, it not only adds a transaction to the system, it possesses a point value which is determined by its characteristics. Table 1 provides a breakout of the possible point values and their characteristics.

When a voucher enters the system, it is reviewed for characteristics, assigned a point value, date stamped, and placed in the "to-compute" queue. Once it is computed, it is placed in the "to-audit" queue. When a voucher is audited it counts for point and voucher totals processed (2; 4; 7).

Data collection includes: (1) the daily voucher

Table 1

Voucher Point Value	Characteristics of Voucher
.5	Advance payments, group vouchers.
1.0 2.0	CONUS, PCS, TDY, vouchers with single destination and return.
3.0 4.0	PCS from outside CONUS or with TDY enroute, TDY with multiple destination and/or fund cites.
5.0 and higher	TDY with travel outside CONUS, PCS from outside CONUS with TDY enroute.

Table of Voucher Point Values and Characteristics arrival rate; (2) a sample of the points assigned to the vouchers; (3) the number of vouchers processed daily; and (4) the total daily points processed. In addition, for start-up conditions (discussed later) the number of vouchers remaining in each of the queues at the end of each day must be recorded. ACFTT management maintains records on all section activities from 1 September 1981 to the present. However, a breakout of the queue end-of-day balances was recorded for only the first 15 days of September 1981. Therefore, for validation purposes (discussed later) the overall ending daily balance is needed.

All data required for the computors and auditors was identified and available for collection from ACFTT. In addition to the number of personnel assigned during the observation period, we also required the individual's processing speed and productive hours each day. These items were required due to our definition of productive processing, which is the actual computing or auditing of a voucher, and does not include any administrative functions. Non-productive time, for the purpose of this simulation, includes such things as customer greeting activities (counter work), phone answering, and other officially related functions. In order to compute an individual's productive reliability, such items as leave time, both sick and annual, temporary duty, on loan, and absent without leave needed to be collected.

One note concerning the auditors must be made. These individuals can also compute vouchers, even though computors cannot audit (7). Therefore, statistics on computation processing speed and productive time were required on the auditors, in addition to their normal audit processing data.

Normally, processing is done in what is referred to as "the back" but can be done by the personnel assigned on a daily random basis to customer service (the counter) (7). This productive time occurs infrequently but must be collected and recorded.

Summary

Here in Chapter II we outlined the steps used to build our model of the ACFTT system. We defined the boundaries of our model and its key inputs. Also provided was a brief overview of the data required to make our model representative of the real world ACFTT system.

CHAPTER III

MODEL FORMULATION

Overview

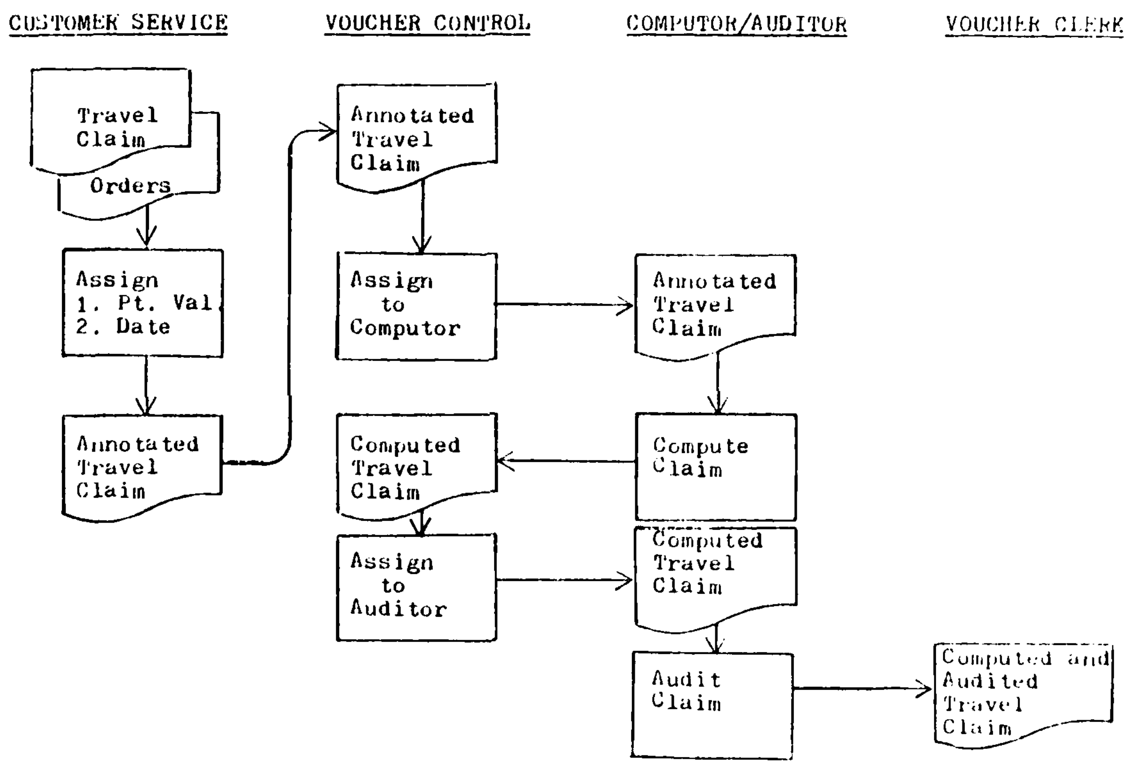
In this chapter we outline the steps taken in building our simulation. The process begins by referring to the input-process-output model developed in Chapter II. With that model in mind, we provide a detailed description of the voucher flow through ACFTT. We then subdivide our initial model into: (1) timing circuit; (2) voucher arrival; (3) personnel arrival; (4) computation process; and (5) audit process. Once this classification is complete, we introduce the required data elements and identify their interaction within the defined system. We then proceed to the formulation of a Q-GERT model requiring logic verification by ACFTT supervisory personnel.

System Description

The model depicted in Figure 2-2 provides a general overview of the ACFTT system. However, in order to better understand the system's interworkings, a more detailed model is required. This model was provided by ACF management in the form of a rough document flow chart (see Appendix A) prepared by the ACFTT supervisor.

As identified in this flow chart, the only input to the system is the travel claim (voucher) itself. These inputs are received via base distribution, deliveries, customer service arrivals (at the counter), and permanent-change-of-station (PCS) in-processing. Once the vouchers enter the system, there are required steps (2 through 10) which must be performed but which are considered non-productive under our definition of processing (the actual computation and audit of a voucher). The initial step in productive processing begins with arrival of the vouchers at voucher control. Here the vouchers are assigned to a computation clerk who does the necessary computations and returns them to voucher control. Voucher control then takes the computed vouchers and assigns them to an auditor who checks for accuracy. An audited voucher represents the completion of the productive processing, but not of the computation section's processing of the voucher. The document flow chart identifies additional steps (13 through 15) which are non-productive, but which must be completed prior to clearing the voucher from the computation system of ACFTT. These latter non-productive steps are done by the voucher clerk, who does not actually process a voucher under our processing definition (4). Figure 3-1 depicts the ACFTT system in a document flow chart with all non-productive actions except customer service removed.

Figure 3-1



ACFTT Productive System Document Flow Chart

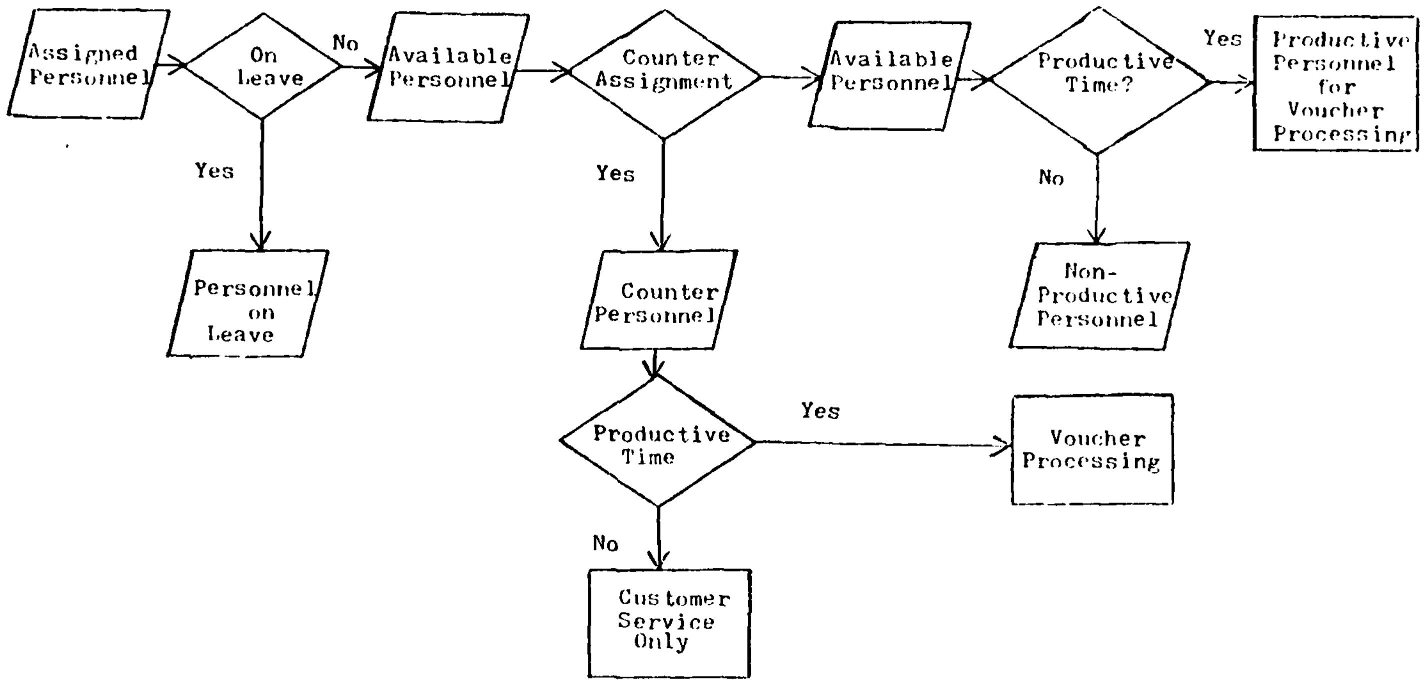
Each of the flow charts (Appendix A and Figure 3-1) implies that vouchers are the only inputs to the ACFTT system. However, without computors and auditors, processing of the vouchers cannot occur. Therefore, for our purposes, the personnel assigned to ACFTT were considered as inputs.

The availability of personnel changes with each workday as individuals take leave, perform non-productive duties, and are assigned to customer service duties (counter). A model of personnel availability is shown in Figure 3-2.

This personnel availability subsystem is in operation at the beginning of each workday, which introduces another section of the overall model, the timing subsystem. Once the personnel arrive, they face an eight-hour workday which is broken by the lunch hour and two fifteen minute personal periods. During this workday, the vouchers arrive steadily over the counter, at three different times from the distribution system, and once from the PCS in-processing. The office closes after the eight-hour workday and personnel depart. The statistical attributes of the system are recorded by the personnel throughout the day and serve as a historical record for collection and analysis.

We have generally described all of the components

Figure 3-2



Personnel Availability Model

of the model. In summary, these components are: (1) the timing circuit; (2) the voucher arrivals; (3) the personnel arrivals; (4) the computation process; and (5) the audit process. With this description and identification, we can group each of the components and analyze its interaction with the rest of ACFTT.

Model Components

Timing Circuit

The major function of this subsystem is to control the timing and duration of a simulation run. However, it must also control the start-up conditions, the initial arrival of personnel and vouchers, and the assignment of personnel to customer service. In addition, this subsystem must collect statistics on the daily activities.

The timing of this simulation is in hours and fractions of hours. This is due to the eight-hour workday, the measurement of productivity in hours, and the measurement of worker speed against an hour. The duration of the simulation matches our data collection period, which was 65 workdays, or 1560 hours. This duration figure must also consider the start-up conditions of the system and the collection of statistics on the last day. Therefore, 14.5 hours were added to the 1560 hours for a simulated run of 1574.5 hours.

The start-up conditions have to be controlled by the timing circuit due to their one-time occurrence at the beginning of the simulation. Since we are modeling an existing system, our model should not start up empty. It can be idle, with no processing occurring, due to the eight-hour workday, but during this idle period vouchers are waiting in the queues for the next day. The insertion of vouchers into the queues represents our effort to control the start-up and ensure a quicker transition to a steady state. The vouchers will be waiting from the prior day close of business for the arrival of personnel on the first simulated duty day.

Under normal operations, when personnel arrive, two individuals are assigned to the counter. Our counter assignments are made based on individual historical trends and are controlled by the timing circuit. The timing circuit also controls the initial arrival of personnel to ensure that the counter assignments are made prior to personnel arrival.

Once personnel arrive for work, a four-hour time lapse occurs until the arrival of vouchers. This time lapse is a compromise position with the real world system. As stated earlier, the vouchers arrive at differing times throughout the eight-hour workday. We feel, however, that a once-a-day mass arrival pattern will closely approximate the average daily "in-queue" waiting times. Under the real system, vouchers can be taken from the counter to the back (productive area) many times during a day, depending upon counter activity. Our timing circuit controls the initial voucher quantity with a subtiming circuit controlling each day's arrivals thereafter.

The next major activity on the timing circuit is the daily collection of system attributes. Since no civilian overtime was allowed during our 90-day study of the real system, and because military overtime amounted to no more than $1\frac{1}{2}$ hours, we felt that data collection at a simulated time of 1800 hours would suffice. The statistics collected at this time included voucners processed, voucher points processed, and the actual number of vouchers waiting in the "to-compute" and "to-audit" queues. This statistic collection method allowed us to measure each day's activity, and in the validation step we were able to test our models against the real system. Following this collection point, our system is idle overnight until 0800 hours the next day, when the counter assignments are made for that day. Appendix B contains our timing circuit flow using Q-GERT symbology.

Voucher Arrivals

In the real system, when the vouchers arrive at the counter, they are marked with the Julian date, reviewed for point characteristics, and assigned a point value determined by those characteristics. The vouchers then wait until someone has the time to deliver them to the back for computation. Our voucher arrival circuit must parallel these activities in addition to rejuvenating itself 24 hours later for the next arrival of vouchers. Our simulation model performs this regeneration training process when the voucher arrival circuit is keyed by the timing circuit. The arrival circuit then calls a random sample of the mail arrivals and decrements itself by one as it releases each voucher which arrives. The decrementing process parallels the mark-review-assign process in the real system. However, unlike the real system, our simulation model places the voucher instantly into the "to-compute" queue. Appendix C depicts the Q-GERT flow chart for voucher arrivals.

Personnel Arrival

Once the initial arrival of personnel is keyed by the timing circuit, the personnel arrival must be re-keyed 24 hours later. This step is completed at the beginning of our personnel arrival circuit along with the assignment of numbers to each of the thirteen computors

(31-43) and six auditors (21-26). We next had to determine who was available for duty. Completion of this step allowed us to draw a productive time sample for each individual available. The auditor portion of this circuit must draw both a productive audit and productive compute sample. These samples are combined and compared to eight hours to ensure that no overtime is worked. Then, knowing that the individual is productive, we draw a random sample of his possible processing speeds. Each individual available now has an assigned processing speed and productive time. Not all of these individuals will process vouchers; two of them must work the counter. So, a check is made to identify these individuals and a sample is drawn for their productive status. If they are productive, then a sample of their counter processing speed is taken and all individuals report for duty. Appendix D is the Q-GERT flow chart of this selection and assignment process for the computors, and Appendix E is for the auditors.

Compute Process

As mentioned earlier, each computor has a set standard of 1. point per fifteen minutes productive time. The computor is assigned a batch of vouchers from the voucher control point. The processing time it takes to complete work on those vouchers varies with each worker, depending upon his respective skill and knowledge.

Each member's processing time is calculated using the relatively simple formula of:

$$\text{Productive Time} = \frac{\text{voucher point value}}{\text{individual processing speed}}$$

In our model the processing time is computed each time a voucher and computor are matched and the result is then subtracted from that worker's available productive time. A check is then made on remaining productive time available and, if any exists, the computor returns to the queue for additional voucher processing. If no productive time remains, the computor is routed out of the system when the necessary statistical information has been collected.

A computed voucher can take one of three paths, based on the probabilities we collected from ACFTT data. If all the information required to process the voucher was available to the computor, the voucher goes into the vouchers-to-be-audited queue. A voucher can be suspensed when a minor piece of the required processing information is missing. When this happens the traveler is notified as to what information is required and asked to make that information available to ACFTT. Usually a suspensed voucher can be computed, but all the member's travel claims may not be reimbursed. A suspensed voucher does not leave the ACFTT system, and takes an average of 48 hours to clear. That 48-hour delay does not count against the three-day standard. The third route a voucher may take is to be returned to the traveler. Returned vouchers require processing time by the computor, but lack sufficient information for complete computation. In this case the worker counts the time spent processing, but the voucher completely exits the ACFTT system. It returns with a batch of incoming vouchers at a later date and must again undergo the complete computation process. Appendix F shows the computation process in a Q-GERT flow chart, from entry in the to-be-computed queue until the voucher and computor take their respective paths (of those discussed earlier).

Audit Process

Processing time for the auditors is computed using the same formula the computors use. The audit process begins when a batch of computed vouchers is assigned to an auditor from the voucher control point. As with the computors, the time it takes an auditor to process a voucher is subtracted from the productive time. A check is then made on that auditor's productive time remaining. If no productive time remains, our model routes the auditor out of the system and collects the needed statistics. An auditor who still possesses productive time is sent back to the auditor queue to continue voucher processing.

Computation mistakes, if any, found by an auditor are corrected and the voucher is routed out of the ACFTT system with the Q-GERT functions collecting our needed statistical information. Appendix G is a Q-GERT flow chart of the voucher audit process.

Data Elements

Our next step in the iterative process of model building was the use of user functions to introduce input data elements. A user function is a "user written program insert that models specialized situations [9:235]." Employing user functions for our model enabled us to simulate the following processes:

1. System start-up conditions
2. Selection of individuals to work the counter
3. Daily sample of worker arrivals
4. Computors' daily productive times and speeds
5. Auditors' daily productive times for computing/auditing, and their work speeds
6. Daily statistical collections

Appendix H is a Q-GERT program listing of our model; Appendix I is a program listing of our user functions and associated subroutines. Variable definitions are found in Appendix J.

Subroutines COMPUTE and AUDIT are functions where the point value of the voucher currently being processed is called through the user of the Q-GERT function

DPROB. The voucher type is divided by the individual's processing speed and the result is placed in the variable WORK, which controls the length of processing time. WORK is subtracted from the individual's productive time and the new productive time is carried forward for later comparison against 0.0 as a check for additional processing.

The HARRIS Q-GERT language allows a maximum of 850 transactions to be in a modeled system at one time. This presented a problem, since at one time the real system contained 882 vouchers. In order to overcome this problem and to allow our model to parallel the real system we divided the arrivals, the remaining voucher quantities, and the individual productive times by two. We then multiplied our outputs by two to determine the performance of our simulation versus the actual data of the real world ACFTT system. The completion of this data interface allowed us to move on to the verification phase of our model building process.

Verification

Verification is "insuring that the model behaves the way the experimenter intends [12:30]." We felt that the NCOIC/ACFTT would be the best person to help us complete this step.. After a detailed walkthrough with him, we learned that the logic of our model paralleled the real world system. The NCOIC also felt that the model could be used to project manpower requirements by varying the parameters of the major inputs. He did disagree slightly with two sets of our model's parameters, processing speeds and productive times. His reasoning was that on any given day when the number of personnel available for duty was higher than normal, productive times and processing speeds would increase. This, he felt was because there were more people to take phone calls, answer questions, etc. Interruptions overall would be fewer, with a resulting increase in times and speeds. We discussed these points with him and after explaining in detail the statistical analysis performed on the data, we agreed that the parameters established for the productive times and process speeds were good working averages for our model. With this agreement, we felt that the model had been adequately verified as representing the real ACFTT system and was ready for validation.

Summary

This chapter presented the final stages of our iterative model building process. Here we grouped the model into its components, explained activity flows, and introduced data elements. Finally, we submitted verification of our model by the NCOIC/ACFTT, which made us ready to collect and analyze the data required to run our model as a simulation.

CHAPTER IV

DATA COLLECTION AND ANALYSIS

Overview

Chapter I of this thesis presented a broad overview of the workings of ACFTT and showed how a Point System for the processing of travel vouchers had been devised by ACF management. That overview led to the problem of being able to use the points/vouchers processed (output) by ACFTT as in input into personnel requirement projections.

Chapter II outlined a methodology which was used to build a simulation model that can be used by ACF to project the number of personnel required to process travel vouchers within the three-day limit.

How the individual components of our model were identified and built was discussed in Chapter III. Once the components were fit together in our model, the logic flow was verified by the NCOIC/ACFTT.

In Chapter IV we will identify how we determined the required forms and formats of our model's input data, and explain how some of the data required manipulation in order to fit our requirements.

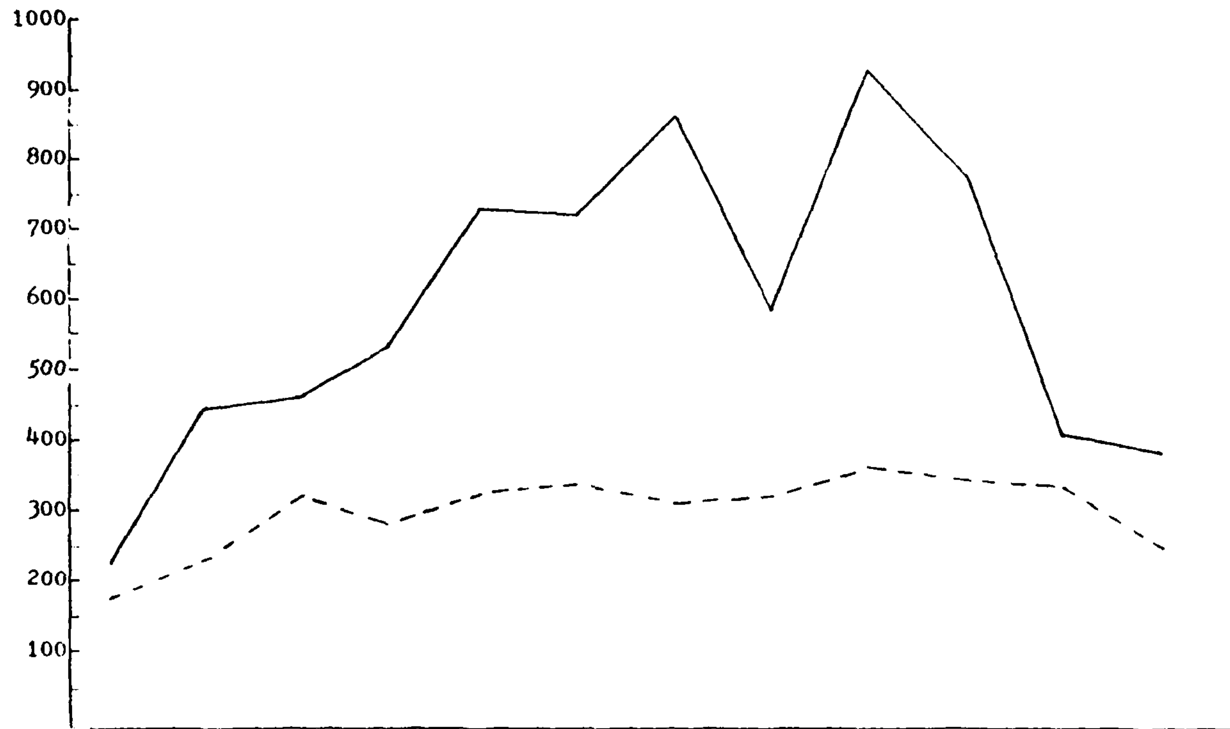
Data Collection

We divided our data requirements into one of two categories, voucher or personnel. These categories were then subdivided into the individual information sets required by each of our model's inputs and for validation of its outputs.

One of the required steps in any simulation process is validation, which "tests the agreement between the behavior of the model and that of the real system [12:30]." We felt that a more accurate reflection of the present system's capabilities would come from using the most recent data available: March, April, and May 1982.

Since additional voucher data was required for representation purposes, we decided to collect a sample of a year's data base. An examination of voucher productivity charts prepared for monthly staff meetings showed a seasonal pattern (see Figure 4-1) to voucher flows, which holds true over the years for the available data (2; 4; 7). We elected to select our data sample on a month-within-a-quarter basis to ensure a spread of sample data over the year and high-medium-low activity months. Our first selection was September because it is the last month of the fiscal year and Air Force "close-out" procedures require all on-hand travel vouchers to be processed by September 30. Next we consulted a random number table and selected March, April, September, and December as the sample months for additional voucher data collection. Since the data for March and April

Figure 4-1



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
On Hand	226	441	459	535	733	717	857	589	926	778	401	375
Received	180	234	315	282	329	336	306	314	358	345	339	247

Voucher Productivity Graph

was already required, we had only to collect data for September and December 1981.

A final item required under the voucher category was a sample of the individual voucher type (points) processed during the most recent three months. The average number of vouchers received each day was over 200 (7), and with this point in mind, we opted to draw a random sample of four days out of 20-22 weekdays each month in order to ensure a good sample. We employed the Texas Instruments Model 58's random number generator and selected the days shown in Figure 4-2. To ensure that we did not double count, our sample was drawn on the vouchers processed by the auditors on the sampled day.

Figure 4-2

March	April	May
1	1	11
8	8	14
22	13	24
23	26	25

Days Sampled for Individual Voucher Points

General Data Analysis

When our data collection was complete, we loaded the information sets into separate files on the AFIT

HARRIS computer system. The use of this computer allowed access to Q-GERT and to the Statistical Package for the Social Sciences (SPSS). The options available with SPSS enabled us to analyze, test, and verify our collected raw data.

The first statistical analysis on our data sets was done using the CONDESCRIPTIVE option of SPSS (Figure 4-3). This option gave the raw statistics of our data--mean, maximum, minimum, standard deviation, etc. The maximum and minimum values recorded as outputs from the CONDESCRIPTIVE run were then used as inputs for the FREQUENCIES SPSS program. The FREQUENCIES option (Figure 4-4) takes the raw data and separates it into ten different groups.

Visual observation of the frequency distribution runs helps identify hypothetical distributions which can be tested using a variety of goodness-of-fit tests available with SPSS. The primary determinant of which test to use is the sample size. "There is little reason not to use the Kolmogorov-Smirmov (K-S) test in the range of $99 > n > 10$, where n is the sample size [9:79]." Since our sample size is less than or equal to 65, the K-S goodness-of-fit test met our requirements.

The K-S test computes: (1) the cumulative distribution of the observed data, (2) the theoretical distribution, and (3) the difference between the two. "A Z-score is then computed for the largest difference

Figure 4-3

```
RUN NAME            BACK COMPUTORS RAW STATISTICS
VARIABLE LIST       NR, TIME, SPEED
INPUT FORMAT        FREEFIELD
INPUT MEDIUM        COMPB
VAR LABELS          NR, COMPUTORS' DAILY PRODUCTIVE TIME/
                    SPEED, BACK COMPUTORS' DAILY POINTS
                    PER HOUR
MISSING VALUES      TIME  (0.0)/SPEED (100.)
*SELECT IF          (NR EQ 1)
CONDESCRIPTIVE      TIME, SPEED
STATISTICS          ALL
READ INPUT DATA
END INPUT DATA
FINISH
```

EXAMPLE OF SPSS CONDESCRIPTIVE PROGRAM

Figure 4-4

```
RUN NAME          BACK COMPUTORS' FREQUENCY CHARTS

VARIABLE LIST     NR, TIME, SPEED

INPUT FORMAT      FREEFIELD

INPUT MEDIUM      COMPB

VAR LABELS        NR, COMPUTORS' NUMBER/TIME, BACK COMPUTORS'
                  DAILY PRODUCTIVE TIME/SPEED, BACK COM-
                  PUTORS' DAILY POINTS PER HOUR

MISSING VALUES    TIME (0.0) / SPEED (100.)

*SELECT IF        (NR EQ 1)

*COMPUTE          MAX = 9.5

*COMPUTE          MIN = 0.0

*COMPUTE          XMAX = 19.11

*COMPUTE          XMIN = 4.0

*COMPUTE          DIFF = ((MAX - MIN) * 1.01)

*COMPUTE          XDIFF = ((XMAX - XMIN) * 1.01)

*COMPUTE          INT = (DIFF / 10)

*COMPUTE          XINT = (XDIFF / 10)

*COMPUTE          CLASS = TRUNC((TIME - MIN) / INT)

*COMPUTE          XCLASS = TRUNC((SPEED - XMIN) / XINT)

*COMPUTE          TIME = ((MIN + (INT / 2)) + (CLASS * INT))

*COMPUTE          SPEED = ((XMIN =(XINT /2)) + (XCLASS * XINT))

FREQUENCIES       GENERAL = TIME, SPEED

OPTIONS           3,7,8

READ INPUT DATA
END INPUT DATA
FINISH
```

EXAMPLE OF SPSS FREQUENCIES PROGRAM

(positive or negative) [3:224]." This computed difference (Z_{COM}) is compared to the values contained in a K-S critical value (Z_{TAB}) table. If Z_{COM} exceeds Z_{TAB}, the hypothesis that the data came from a particular distribution is rejected.

K-S critical values are determined based upon the sample size, which is known, and a significance level is chosen:

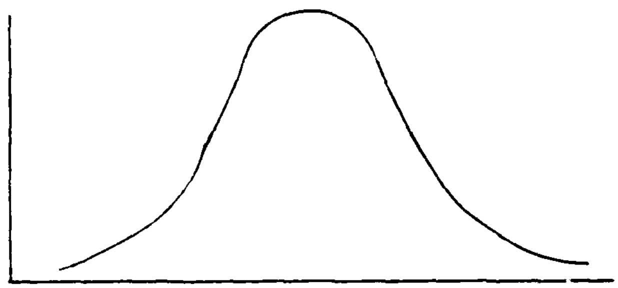
> ...based on the seriousness of the type I error (rejecting H_o, or the hypothesized distribution, when it is not true) as opposed to type II error (accepting H_o when it is false) [8:268].

If a type I error is very serious, a low significance level is set (i.e. .001) while a high significance level (i.e. .10) is set if a type II error is more serious. We determined that an acceptable compromise would be a significance level of .05, and that value was used in all statistical tests.

The results of the FREQUENCIES program indicated that we would generally be interested in three types of distributions: normal (NO), lognormal (LO), and uniform (UN). Figures 4-5, 4-6, and 4-7 show examples of these types of distributions.

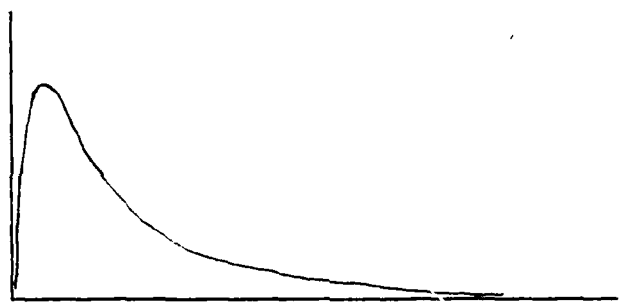
One data modification we performed was to subtract raw data entries from a constant value to help identify a distribution type. This manipulation was done for certain computors and auditors, and is fully explained at the points where the modification occurred.

Figure 4-5



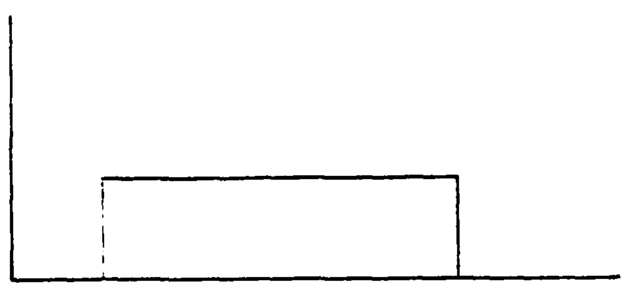
Example of a Normal Distribution

Figure 4-6



Example of a Lognormal Distribution

Figure 4-7



Example of a Uniform Distribution

Voucher Data Analysis

The voucher data we collected included vouchers received, processed, returned, suspended, and remaining, and points received and processed. The results of the FREQUENCIES program indicated that we would be concerned with LO and NO distributions. Thus, our H_0 for these Goodness-of-Fit (GOF) tests was the sample data distribution equaled our hypothesized distribution, with our alternative hypothesis being that the sample data distribution did not equal the hypothesized distribution.

The GOF test used was the K-S and, as stated earlier, we would not reject the null hypothesis if the calculated value was less than the critical table value. Table 2 presents the results of these GOF tests as measured against the critical values. Having identified the voucher distribution types, we then extracted the data needed for input to our Q-GERT simulation program.

To draw random samples for program inputs, Q-GERT requires a distribution identification (NO, LO, or UN) plus the mean, minimum, and the maximum values, the standard deviation, and a seed value. The distribution identification appears in the program function where the sample is called, while the parameters are placed on parameter cards (PAR) in the order listed above.

Table 2

Data Set	Vouchers Received	Vouchers Processed	Point Value Processed	Vouchers Returned	Vouchers Remaining	Suspended Vouchers	Critical Values
Most Recent	LO-.0622	LO-.0668	NO-.0719	LO-.1482	LO-.0760	______	.1687
Sept. '81	LO-.1906	LO-.1014	LO-.1106	LO-.1244	LO-.1577	NO-.2648	.2968
Dec. '81	NO-.1408	NO-.0790	NO-.1062	NO-.2223	NO-.1154	NO-.1722	.2900
Mar. '82	LO-.2321	NO-.1225	NO-.1121	LO-.1802	NO-.1452	LO-.2225	.2836
Apr. '82	NO-.1506	LO-.1302	NO-.1038	LO-.1870	LO-.1291	LO-.2035	.2900
Combined	NO-.1046	LO-.0865	NO-.0708	______	LO-.0651	______	.1458

Distribution Type-Calculated Value

Results of Voucher Data GOF Tests

The "vouchers received" and the "vouchers remaining were the only two voucher data inputs required for our program. The remaining data was used as a base against which we compared our program output for validation purposes. The "vouchers received" represent the combined total of the vouchers arriving from the mail, counter arrivals, and personnel in-processing, with a parameter input of:

PAR,2,224.677,96.,498.,80.,10*

The "vouchers remaining" representing start-up conditions are explained in Chapter III, and have parameters of:

PAR, 10, 476.846, 148.,882.,188.903,10*

Each of the above represents voucher input data for our "most recent" program run. Once this program is verified and validated, the above card values are replaced to perform the "experiment" runs. Table 3 represents the changes made on these cards.

Upon its arrival in the Travel system each voucher is assigned a point value depending on the characteristics of the voucher. We drew a random sample of these vouchers, as outlined earlier, performed a count of each voucher type, summed the count and divided the individual sums by the total sum to obtain a percentage distribution of the assigned points. Table 4 gives the results of these calculations.

Table 3

	Mean	Minimum	Maximum	Standard Deviation
PAR,2				
Combined Data	217.115	22.0	499.0	95.331
Highest Arrival Month	257.476	170.0	499.0	78.509
Lowest Arrival Month	160.227	22.0	499.0	97.286
PAR, 10				
Combined Data	537.057	88.0	1114.0	255.155
Highest Arrival Month	815.905	560.0	1114.0	201.369
Lowest Arrival Month	314.5	88.0	479.0	96.947

Voucher Experimental Data Inputs

Table 4

Voucher Point Value	Count	Percent of Total
.5	258	11.67%
1.0	1562	70.65%
2.0	294	13.30%
3.0	73	3.30%
4.0	9	.41%
5.0	15	.67%
	2211	100.00%

Assigned Voucher Point Distribution

These point values and their associated percentages were entered as DPROB values under the COMPUTE and AUDIT subroutines of our model's user functions.

Personnel Data Analysis

Our sampling plan for the personnel was confined to the most recent three months. Not only is this data required to validate the model, we feel that it more closely reflects the training and experience of the currently assigned personnel. The data includes the processing speeds, productive times, and availability times (i.e. on leave, TDY, on loan, counter work, etc.) for all auditors and computors during March, April, and May 1982. This data was used in the validation and experimental runs. Since the auditors can both audit and compute a voucher, separate data was collected on both processing speeds. The combined productive times for the auditors was compared to a maximum of eight workhours to ensure valid entries. The overall personnel data base was segregated into "counter" operations and "back" operations. The personnel assigned to the counter are considered mostly non-productive, but when time permits, can process vouchers (2; 4; 7). Thus, our data analysis for personnel inputs was collected by auditors, computors, and counter operations.

The only data that we manipulated was that collected on the computors and auditors. As stated earlier, these individuals have certain military or military related additional duties which must be performed. These duties can take all or part of a day. If only part of the day is consumed, the remainder of the time is spent processing vouchers. When any part of a day is used for processing, a productive hourly figure is recorded along with the individual's processing speed for that day. However, if the additional duties consume the entire day, then the productive time and processing speed are recorded as zero. This situation was identified in our data collection as a missing value.

When using SPSS options, a missing value can be read by the computer program if it is first defined as missing. Therefore, whenever an individual recorded a non-productive day, we entered a value of 100. for his processing speed and defined it as missing. This missing value modification ensures that statistics calculated on the processing speeds include only the actual speeds encountered. It also indicates that on any day, an individual, based upon historical data, will have a calculated reliability of performing productive work.

Reliability is defined as "the probability that the system will perform up to specifications a specified number of times under prescribed conditions [10]."

Using this definition as a base, our reliability definition became the probability that an individual (computor or auditor) will be productive (voucher processing) a specified number of days. Each military individual is allowed a certain number of leave days a year, while a civilian is allowed leave days plus a set number of sick days per year. So, for any day an individual must be on leave, non-productive, or productive, with time and speed recorded.

We calculated each individual's reliability to the ACFTT system by using the formula:

$$R = AFD(P \div TWD) \text{ with } AFD = 1 -(LD \div TWD)$$

where:

R = individual's overall reliability
AFD = available for duty probability
P = individual's productive days
TWD = total workdays
LD = individual's leave days

The obtained reliability figure then allowed us to determine productive/non-productive times. Such dicotomous determinations "are called Bernoulli variables and are characterized by the binomial distribution [12:1913]." For our purposes the binomial distribution was the probability of an individual's reliability on a selected day, given the number of available workdays, and that individual's productive days. We knew each individual's historical reliability figure and AFD, but not his daily Bernoulli (productive/non-productive) variables. So to solve for the productive variable we changed our reliability equation to:

$$P \div TWD = R \div AFD$$

Once a productive probability was known, subtraction from 1 gave the required non-productive probability.

Having made these calculations, we declared the time value of 0.0 as missing, which allowed us to statistically test only the productive times and processing speeds.

<u>Auditors</u>

The output of the FREQUENCIES run indicated that the processing speeds for the auditors approximated a lognormal distribution, while the distributions of the productive times varied. Of the six auditors, three distributions appeared normal while another appeared lognormal. The remaining two distributions approximated lognormal distributions if the data entries were subtracted from a constant value. Since none of the auditors worked more than eight hours a day, we selected the value of eight for our constant. The result of this manipulation was that the last two data sets approximated a lognormal (LO(8-)) distribution.

Using the above theoretical distributions, we tested our null hypothesis using the K-S GOF test. The computed values weighed against the critical table values (see Table 5) indicated there was insufficient evidence to reject the null hypothesis, which was that the raw data distributions equaled the hypothesized distributions.

Table 5

Auditor Number --Data Type	Hypothesized Distribution	Calculated Value	Critical Table Value
1-Time	NO	.0976	.1713
1-Speed	LO	.0691	.1713
2-Time	LO(8-)	.1627	.1868
2-Speed	LO	.0899	.1868
3-Time	NO	.1433	.1886
3-Speed	LO	.1425	.1886
4-Time	LO(8-)	.1210	.1963
4-Speed	LO	.1193	.1963
5-Time	NO	.0875	.1904
5-Speed	LO	.1055	.1904
6-Time	LO	.1655	.2400
6-Speed	NO	.2782	.2400

Results of K-S GOF Tests for Auditor Data

Computors

The individual FREQUENCIES runs on the computors' times and speeds indicated a range of distribution types which included normal, lognormal, lognormal (8-), and uniform. We also encountered extreme difficulty in fitting a distribution type to the computation speed for the auditors. In these cases, after attempting GOF tests under normal, lognormal, and uniform distributions, we decided to use the Q-GERT function DPROB, which randomly selects an expected value based on given percentages. Table 6 identifies the distribution type and K-S values for computors' productive times and speeds and auditors' compute speeds not using DPROB. Once again, we used earlier CONDESCRIPTIVE tests to prepare the required parameters.

Counter Operations

The FREQUENCIES results for the computors' and auditors' productive times identified a hypothesized distribution type of lognormal. However, the missing values or non-productive times equated to about 35% of the total time. Therefore, we split the distributions into Bernoulli variables (productive or non-productive samples) followed by a sample of the tested distribution of the Bernoulli sample indicated productive time. We then dropped the non-productive entries and tested the remaining entries for a fit to lognormal distribution. The counter computors' GOF calculations provided a value of .0943, which when weighed against the critical table value of .2483, provided insufficient evidence to reject the null hypothesis that the sample data distribution fit a lognormal distribution. The counter auditors' calculated value of .2332 was less than the critical table value of .3205, again providing

Table 6

Computor Number --Data Type	Hypothesized Distribution	Calculated Value	Critical Table Value
1-Time	LO(8-)	.1219	.1923
1-Speed	NO	.1121	.1943
2-Time	NO	.1305	.2617
2-Speed	UN	.1140	.2617
3-Time	LO(8-)	.1039	.2776
3-Speed	LO	.1481	.2776
4-Time	NO	.1341	.2124
4-Speed	LO	.0762	.2124
5-Time	LO(8-)	.1211	.1943
5-Speed	NO	.1548	.1967
6-Time	LO(8-)	.1453	.2178
6-Speed	LO	.0920	.2178
7-Time	LO(8-)	.1955	.2150
7-Speed	LO	.1323	.2236
8-Time	NO	.0785	.2099
8-Speed	LO	.0877	.2099
9-Time	NO	.1523	.2483
9-Speed	NO	.0950	.2483
10-Time	LO(8-)	.1503	.2050
10-Speed	LO	.1514	.2050
11-Time	NO	.1622	.2367
11-Speed	LO	.1303	.2367
12-Time	NO	.1254	.2367
12-Speed	LO	.1887	.2367
13-Time	NO	.0856	.1834
13-Speed	NO	.0787	.1834
14-Time	LO	.1301	.2098
14-Speed	DPROB used		
15-Time	NO	.1388	.3041
15-Speed	DPROB used		
16-Time	DPROB used		
16-Speed	DPROB used		
17-Time	LO	.0962	.1904
17-Speed	DPROB used		
18-Time	LO	.1107	.1834
18-Speed	DPROB used		
19-Time	DPROB used		
19-Speed	DPROB used		

Results of K-S GOF Tests for Computor Data insufficient evidence to reject the hypothesis that the data came from a lognormal distribution.

The counter operations speed FREQUENCIES run provided us with an easy identification of the computors' speeds, which were all entered at 4.0 points per hour. Thus, a constant value of 4.0 was used whenever these individuals worked a voucher. However, the counter auditors showed quite different results. With the speeds recorded for these individuals, we could not identify a distribution type. Therefore, we decided to again use the Q-GERT DPROB function. We performed the physical count of the speed entries and performed the calculations which showed speeds of: 8.0 (83.3%), 8.5 (5.56%), 10.0 (5.56%), and 10.5 (5.56%) points per hour for auditors working the counter. As a result, only two PAR cards were used for counter operation:

Counter Computors' Time- PAR,3,1.556,0.5,3.25,.906
Counter Auditors' Time- PAR,5,3.267,1.25,7.5,1.656

Since the model had been verified earlier, completion of the data analysis step enabled us to enter parameters for our simulation's inputs and make validation runs. Each run produces statistical information on the model's workings. This information is collected by the Q-GERT functions and our specifically designed user function, and includes server use, server processing time, queue waiting times, and average queue size (see Figure 4-8).

Figure 4-8

FINAL RESULTS FOR XX SIMULATION

TOTAL ELAPSED TIME = XXXX.XX

NODE STATISTICS

NODE	LABEL	AVE.	STD. DEV.	NO. OF OBS	STAT TYPE
X[@]	YYY-YYYY[@@]	XX.XXXX	XX.XXXX	XX	Y

NUMBER IN Q-NODE / **WAITING TIME IN QUEUE**

NODE	LABEL	AVE.	MIN.	MAX.	CURRENT NO.	AVERAGE
X	YYY-YYYY	XX.XXXX	X	X	X	XXX.XXXX

SERVER UTILIZATION

SERVER	LABEL	NO. PARALLEL SERVERS	AVE.	MAX IDLE (TIME/SERVERS)	MAX BUSY (TIME/SERVERS)
X	YYY-YYYY	XX	XX.XXXX	XX.XXXX	XX.XXXX

@ NUMERIC

@@ ALPHA

Example of Q-GERT Output

The primary focus in the validation step was to ensure that these statistics closely paralleled the real system.

The end-of-day queue sizes plus the vouchers and points processed on these days provided a strong indication of what was occurring in the real system (2; 4). Therefore, a logic check was made on these outcomes (i.e. the average vouchers processed in a day should not be two times greater than the average points processed) and a comparison of the means ($\overline{X}$) and standard deviation (S) of the real world data was made against the simulated data means ($\overline{X}_s$) and standard deviation (S_s). This comparison was made using the SPSS program T-TEST (Figure 4-9).

The subprogram T-TEST tests the null hypothesis $\overline{X} = \overline{X}_s$ against the alternative hypothesis $\overline{X} \neq \overline{X}_s$ (8:269). The test statistic computed is:

$$t = \frac{(X - X_s) - D}{\sqrt{S_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where:

D = the difference between the means (assumed to be zero)

S_p^2 = the pooled standard deviations squared

n_1 = the first sample size

n_2 = the second sample size

Figure 4-9

RUN NAME	T-TESTS FOR SIMULATION VALIDATION
VARIABLE LIST	RUN, PTPRO, VHPRO, DVREM
INPUT FORMAT	FREEFIELD
INPUT MEDIUM	TAPE2
VAR LABELS	PTPRO, DAILY POINTS PROCESSED/ VHPRO, DAILY VOUCHERS PROCESSED/ DVREM, DAILY VOUCHERS REMAINING
T-TEST	GROUPS = RUN/VARIABLES = PTPRO, VHPRO, DVREM
READ INPUT DATA	
END INPUT DATA	
FINISH	

EXAMPLE OF T-TEST PROGRAM

The value computed (T_{COM}) is compared to the critical table value (T_{TAB}) and if $T_{COM} > T_{TAB}$ then the null hypothesis is rejected. This means that there is insufficient evidence to accept the hypothesis that the means are equal.

To enable us to use this T-TEST, the following assumptions had to be made:

1) The population distributions are normally distributed. 2) The population variances are equal. 3) The samples are randomly and independently selected [5:255].

The greatest problem associated with these assumptions is the equal variances. However, the assumption is verified by performing an F-test whose null hypothesis ($S^2 = S_p^2$) is rejected if F_{COM} is greater than F_{TAB}. The actual test is performed manually and is simply:

$$F = S^2 \div S_p^2$$

The assumptions for this test are the remaining assumptions for a T-TEST.

Summary

This chapter dealt with the identification and collection of data required to make our model ready for validation. How the data was analyzed and tested was explained in depth. Once we had determined the parameters of our inputs, we entered those values into our model on the HARRIS computer. The actual running, for validation purposes, of our simulation will produce output data which must be analyzed and compared to the real world output information.

CHAPTER V

VALIDATION AND MANIPULATION

Overview

Previous chapters have served to identify the steps used to build our model of the ACFTT system. This chapter explains how our model can be used by ACF management to forecast manpower requirements. To culminate the iterative model building process for constructing and running a system simulation, we identify the mathematical and logical validation points our model required. Discussed are the procedures used, including determination of what constitutes a statistically significant sample data size, to ensure our model behaved as intended. Finally, this chapter reports our validation results and how our model's parameters were aligned to give the closest proper representation of the real world ACFTT system.

Model Planning

Model Use

Our objectives were to 1) build a model of the ACFTT system that, 2) could be used to forecast personnel requirements by using voucher arrivals as the controlling input. The objective of running the model as a simulation is to determine what personnel (computors and auditors) input enables the three-day voucher processing standard to be met.

Our model's input values are controlled by the Q-GERT PAR cards. The PAR numbers and their associated inputs are shown in Table 7.

Table 7

PAR	Input
2	Average voucher arrivals
10	Vouchers in ACFTT at simulation start
3	Counter Productive Time, Computor
5	Counter Productive Time, Auditor
2X	Auditor Productive Time
3X	Audit Speed
8X	Compute Speed, Auditor
3X-4X	Computor Productive Time
6X-7X	Compute Speed

Parameter Inputs

To determine the impact to the system of an input's changing, the simulation would be run using a new PAR card containing the necessary parameter changes. The changed input's impact on the system could then be determined by studying the Q-GERT output product described in Chapter IV. The key items to study would be the average waiting time in the to-compute and to-audit queues. The sum of the average waiting time in these two queues should not exceed 52.5 hours. This is the amount of time our model simulates as the three-day standard for voucher processing. If the total queue waiting time exceeds the standard and cannot be adjusted by internal ACF management actions, then the model can be run using different processor combinations to determine what personnel must be hired. We feel that until a learning curve for processors can be established by follow-on research, any new personnel inputs should be made at system average productive times and set standards for point processing.

The experience and knowledge of ACF management should provide an initial intuitive estimate of manning requirements. That estimate could then be verified or adjusted by subsequent runs of our model and presented to the base civilian personnel office as an unbiased, mathematically verified justification for hiring additional personnel.

Validation

Validation is "testing the agreement between the behavior of the model and that of the real system [12:30]."

Once this agreement is confirmed, further validation must ensure "that the inferences drawn from the experiments with the model are valid and correct [12:30]." These validation steps can be completed through a three stage effort.

> The first stage is to seek face validity on the internal structure of the model based upon a priori knowledge, past research, and existing theory.... The second stage is also concerned with the validation of the internal structure of the model, and consists of empirically testing...the hypothesis used...The third stage...entails comparing the input-output transformation generated by the model with those generated by the real world system [12:215-216].

The first stage actually crosses the boundary between verification and validation, for it is here that we used the NCOIC/ACFTT's prior knowledge to verify and validate our model's mathematical equations and voucher flows. The second stage was concluded when we made several preliminary runs to ensure the model behaved as intended. For the third stage, we took our model's outputs and used SPSS programs to statistically compare them to the real system output.

As was stated earlier, vouchers remaining in the queues at workday's end and the number of vouchers processed that day, along with points processed, provide an indication of the internal state of the system (2,4,7). We designed the programming of our model to output the above factors to a data file. This data file was necessary for two reasons: 1) collecting data for statistical testing, 2) enabling a visual day-to-day scan of our model's output to be done by writing the file out to a printer. The visual scan of outputs was important to our validation efforts because "75 to 80 percent of the vouchers remaining each day in ACFTT are in the to-compute queue [7]." Our statistical testing would only indicate whether our model's total vouchers remaining, vouchers processed, and points processed were significantly different from the real ACFTT outputs. So a visual scan of the simulation output along with statistical testing enabled us to validate both logical and mathematical aspects of our model. The logical aspect consists of: 1) ensuring proper vouchers remaining ratio between the to-compute (75-80%) and to-audit (20-25%) queues, and 2) matching processing equations and voucher flows with the ACFTT system. The mathematical aspect includes statistical comparisons of outputs from both systems (ACFTT and model) for: 1) total average remaining vouchers, 2) total average vouchers processed daily, and 3) total average points processed daily. The next step in validating our model so we could safely make inferences was determining the sample size required for statistically significant results.

Sample Size

The sample size may be determined in either of two ways: 1) prior to and independently of the operation of the model, 2) during the operation of the model and based upon the results generated by the model [12:187].

We determined our required sample size by combining the above methods. This was done by determining the size prior to operation of the model, but based on the results obtained in Chapter III concerning the combined March, April, and May 1982 points processed data. The results were such that the points processed took on an individual mean value with a normal distribution. The other outputs of our model also took their own means and could therefore be converted to normal distributions. These characteristics enabled us to envoke the Central Limit Theorem in determining sample size.

The Central Limit Theorem holds that normality of the results can be assumed if each sample is itself a mean (12:187). Using this assumption, we consulted a table listing of various sample sizes based on standard deviations from the mean (12:190). In summary, the table indicated that the lower the standard deviation from the mean desired, the greater the sample size must be. With that point in mind we made our primary consideration the cost to run our simulation based on the central processing unit time used by the computer.

We determined that an acceptable compromise between cost and statistical confidence would be a sample size of 15 runs at a simulated 1574.5 hours each (65 workdays).

This allowed us one-half of a standard deviation from the mean. In other words, if the standard deviation for points processed was twenty, we would be statistically confident at the 95% level that our model's output would be within 10 vouchers of the actual ACFTT mean.

Preliminary Runs

One of the options available with Q-GERT is to print out a listing of all activities taking place for a specified number of runs. We used this option for three days of activity to ensure that the subsystems of our model were working as planned. After numerous debugging runs we succeeded in aligning all portions of the model without making any major structure changes. However, these runs did identify that our start-up samples were extremely high in relation to the allowable Q-GERT transaction size of 850. Therefore, we used for our start-up the same conditions recorded under the real system for March 1982. We felt that this change would provide a more realistic simulation and would enable us to make our validation runs.

Validation Results

With our output divided in half as discussed in earlier chapters, we were reasonably confident that the Q-GERT limitation of a maximum 850 transactions in the system at one time would not be violated. This was because when the transactions representing computors, auditors, and timing circuits were subtracted, we still had approximately 800 transactions to represent vouchers in the system. To double that would mean a possible representation of 1600 vouchers in the system, considerably more than ever existed during the three-month period we were simulating.

However, our first operation of the model at 1574.5 hours for 15 runs resulted in the 850 transaction limitation's being violated at 24 simulated workdays into the first run. Since none of the output data was in agreement with the real world data we had collected, our first thought was that the statistical analysis which had given us our input values was in error. A meticulous recheck revealed one erroneous input, average point value per voucher. We had assigned a point value per voucher that was higher than the real system value. On the average, this higher value would reduce the amount of productive time available by increasing the time it took to process each voucher.

We had calculated an average point value of 1.16 per voucher, while previous research had used 1.04 as the average point value. Since our point value was based only on data from randomly selected workdays in the month, we decided to combine our findings with the previous research findings to obtain the distribution values for voucher points shown in Table 7. After our reevaluation, we input the new point values and ran our simulation again.

Table 7

Point Value	Occurrence Percentage
.5	18.00
1.0	69.42
2.0	10.95
3.0	0.95
4.0	0.59
5.0	.09

Voucher Point Value
Distribution
(Average point value per voucher = 1.06)

The second attempt at validation of our model was also unsuccessful. Twenty-eight simulated workdays into the third run the 850 transaction limit was again violated. An analysis of the output showed the only result statistically acceptable as representing the real system was the average point value of the vouchers processed. Again we reanalyzed our data collected from ACFTT, but this time we could find no errors in the calculation of our input values.

Our model's output showed the computors processing more vouchers daily than the auditors were. Logic dictated, since the number of computors was more than double the number of auditors, that if the real world vouchers remaining ratio were to hold true, then the number of vouchers processed by the computors daily must somehow be reduced. Also, a portion of the vouchers computed is actually handled by the auditors. Logically following then, is that when an auditor computes, the productive time for auditing vouchers is reduced. We theorized that should the auditors be faced with an increasing queue of vouchers needing auditing, they would cease computing vouchers and dedicate their productive time to the auditing process. Unfortunately, the data collected by ACFTT does not include individual daily counts of the vouchers remaining in the to-compute and to-audit queues. This data absence prevented us from doing correlation tests between queue sizes and auditors' productive times. We felt, though, that our theory of correlation could be informally tested if we established confidence intervals for each processor's (computors and auditors) mean productive times and processing speeds, and used the lower and upper boundaries in different runs of our model. This would enable us to decrease or increase our processors' times and speeds to study the impact on our simulated ACFTT system.

We decided that a 95% confidence level was sufficient for purposes of our informal testing. Confidence intervals were established by repeatedly drawing samples, from each individual's historical data, of productive times and processing speeds, and forming a two-standard-deviation interval around the sample mean each time. At our chosen confidence level we were then 95% certain that our established intervals would contain the population mean (5:215).

There are two formulas available for calculating confidence intervals and their use is dictated by the sample size. For a small sample size (less than 30 data points) the formula is:

$$\bar{X} \pm t_{\alpha/2,n-1} \frac{s}{\sqrt{n}}$$

Where:

$\bar{X}$ = sample mean
$t_{\alpha/2,n-1}$ = t statistic with stated degrees of freedom
s = sample standard deviation
n = sample size

For a larger sample size (greater than 30) the formula is:

$$\bar{X} \pm Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

Where:

$\bar{X}$ = sample mean
$Z_{\alpha/2}$ = Z value with ½ its area to the right
σ = sample standard deviation
n = sample size

These two formulas were used as needed to calculate confidence intervals with an upper and lower boundary for each processor's productive time and processing speed. Appendix K shows the calculated intervals.

Our first informal test run was made using the computors' average productive times and speeds. The upper boundaries for process speeds and audit productive times were input for the auditors along with the lower boundaries of their compute productive times. This combination would keep the computors at the level at which they operated during the three months of our data collection, while the auditors would have more productive time at faster processing speeds. We felt that this would give an indication of what would happen to queue sizes if the auditors focused their work efforts on the auditing process.

No violations of the 850 transaction limitation occurred with this combination but the ratio between queues did not reach the desired 75-25 ratio. Neither was the total number of vouchers remaining in both queues unacceptably higher than the real system average ending balance. The number of points and vouchers processed were also higher than the real world data indicated they should be. Because none of the key output points were acceptably close to the ACFTT system's outputs, we decided that any statistical testing would prove to be unproductive.

To research what would happen should the auditors concentrate on auditing, but not feel pressured to speed up the auditing process, we made the previous run again, but used the auditors' average processing speeds. The result was average voucher and points processed figures that were very close to the real world data. Unfortunately, the sought after queue ratios were not achieved, and the total vouchers remaining was again unacceptably high. Since this run also exceeded Q-GERT limitation at 63 days into the second run, no statistical analysis was made. Table 8 is a complete tabulation of the key outputs from the various runs.

Summary

This chapter outlined the validation efforts taken with our model. Using different combinations of confidence interval boundaries verified that increased auditor productive time and speed reduces the number of vouchers computed and increases the total vouchers audited (processed). This strengthened our theory that there exists some type of informal to-audit queue size standard within ACFTT, at which the auditors will cease computing vouchers and restrict their productive time to auditing.

CONDITIONS	AVERAGE DAILY VOUCHERS PROCESSED	AVERAGE DAILY POINTS PROCESSED	AVERAGE VOUCHERS TO-COMPUTE QUEUE/%TOTAL/ WAITING TIME	AVERAGE VOUCHERS TO-AUDIT QUEUE/%TOTAL/ WAITING TIME	AVERAGE TOTAL VOUCHERS REMAINING/ QUEUE WAITING TIME
Average ACFTT outputs for March, April, and May 1982	218.7	231.7	75-80%	20-25%	476.8
All processors at means with 1.16 average voucher point value--ran 24 days into 1 run	196.6	227.8	670.5/ 57/ Overflow	507.3/ 43/ Overflow	1177.8/ Q-GERT Overflow
All processors at means with 1.06 average voucher point value--ran two complete simulations and 28 days into third	207.6	220.4	178.3/ 25/ 3.3	527.3/ 75/ 50.2	705.6 53.5
COMPUTORS: means, productive time (PT) and compute speed (CS) AUDITORS: UCI* Audit PT UCI Audit Speed (AS), LCI** Compute PT, --Completed all runs	237.8	252.0	233.1/ 40/ 21.2	345.8/ 60/ 28.8	578.9/ 50.0
COMPUTORS: means, PT and CS AUDITORS: means, audit DT, UCI AS, LCI compute PT--completed one run and 63 days of second	221.0	232.9	130.0/ 23 3.9	445.3/ 77/ 15.0	575.3/ 18.9

*UPPER CONFIDENCE INTERNAL
**LOWER CONFIDENCE INTERVAL

Simulation Results: Key Outputs

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

We had two stated objectives for conducting this research:

1. To construct a model of ACFTT that will use incoming vouchers as input and points and vouchers processed as output.

2. To determine the number of computors and auditors required to meet the three-day processing standard, given the voucher workload.

The outcome of achieving these objectives is the answer to our research questions:

1. Can a model be developed to accurately reflect the ACFTT based workforce and the Point System?

2. If a model can be developed, can it be used by ACF management to project manpower requirements?

We met our first objective by building an ACFTT model that was verified by two separate methods. The first was to explain each logic flow and mathematical equation in the model to the NCOIC/ACFTT. Except for his theory discussed earlier concerning increased productive time when a larger number of personnel are available for duty, he had no disagreement with the model. He also stated that he could visualize management uses of the model to predict system behavior if the model could be validated.

Our second method of verification was to exercise the Q-GERT option of having a trace printed out of the simulation's inner workings. Using the traced run we manually tracked the model's behavior and were satisfied that it represented the behavior of the real world ACFTT system.

Problems arose though, when we tried to validate our model. The outputs that our simulations produced were not in line with the real system's outputs. We theorized that this was because an informal feedback system exists for the auditors within ACFTT. This feedback loop would cause the auditors to cease computing vouchers and focus their productive efforts on the auditing process when the to-audit queue reaches a certain size.

Since data was not available for individual queue sizes on a daily basis, we were unable to run any type of correlation tests between audit productive times and speeds and the to-audit queue sizes to strengthen our theory. We did devise an informal testing, though, by establishing confidence intervals for the processors' productive times and processing speeds, and then using the upper and lower boundaries of those intervals to make experimental runs.

We found that any increase of the auditors' productive times of process speeds caused the model's outputs to begin approaching the real system's output. The 75-25 compute-to-audit ratio was never reached, but the simulation run with the auditors putting the emphasis on audit productive time did produce acceptable outputs for points and vouchers processed by the ACFTT system.

Since model inputs based strictly on statistics derived from our collected data did not produce any outputs acceptable for validation, we feel that our audit feedback theory was a valid conclusion.

Recommendations

Without model validation our second research objective was not accomplished. Nor were we able to provide positive answers to our research questions. We do feel, however, that we have created a base from which ACF management can operate in their effort to realize a useable ACFTT model for predicting the ACFTT system's behavior under certain conditions.

It is our recommendation that ACF management increase the daily data recordings by ACFTT supervisory personnel to include:

1. Daily counts of vouchers remaining in both the compute and audit queues, recorded as separate figures.

2. Cross-checked totals (prior day, balance, today's balance, and vouchers computed) of computed vouchers.

Collection of these data points will enable future researchers to correlate queue balances with productive times and process speeds and document our theory of an auditor feedback loop.

Areas For Further Study

If our recommendations are are followed by ACF management, then the additional data collected with ACFTT should be analyzed to determine what effect queue sizes have on the processors' productive times and process speeds. Specifically, the daily to-audit queue sizes should be correlated with the auditors' data to establish the point where the emphasis shifts to the auditing process. Success in establishing the audit feedback loop as a real entity could then lead to validation of our model.

After validation of our model, additional research could establish learning curves for ACFTT personnel. This would identify the time required for newly assigned personnel to become fully productive and could be used as an input to the model. We feel that this would provide a more accurate projection of manning requirements.

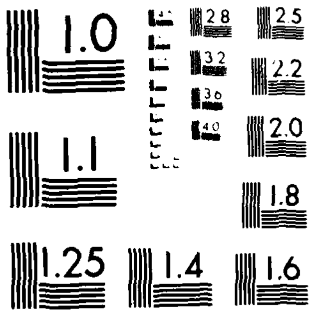
APPENDICES

AD-A124 090 AN EVALUATION OF ALTERNATIVES FOR PROCESSING OF ADMINISTRATIVE PAY VOUCHE..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST..

2/2

UNCLASSIFIED C B VENABLE ET AL. SEP 82 AFIT-LSSR-61-82 F/G 5/1 NL

END
DATE
FILMED
8-83
DTIC



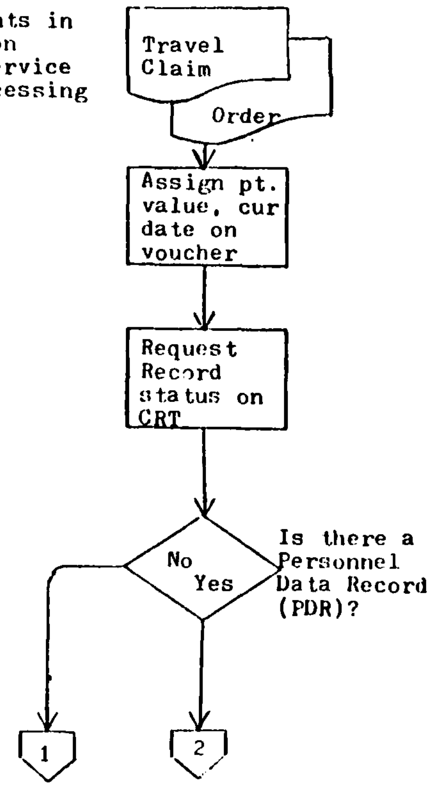
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

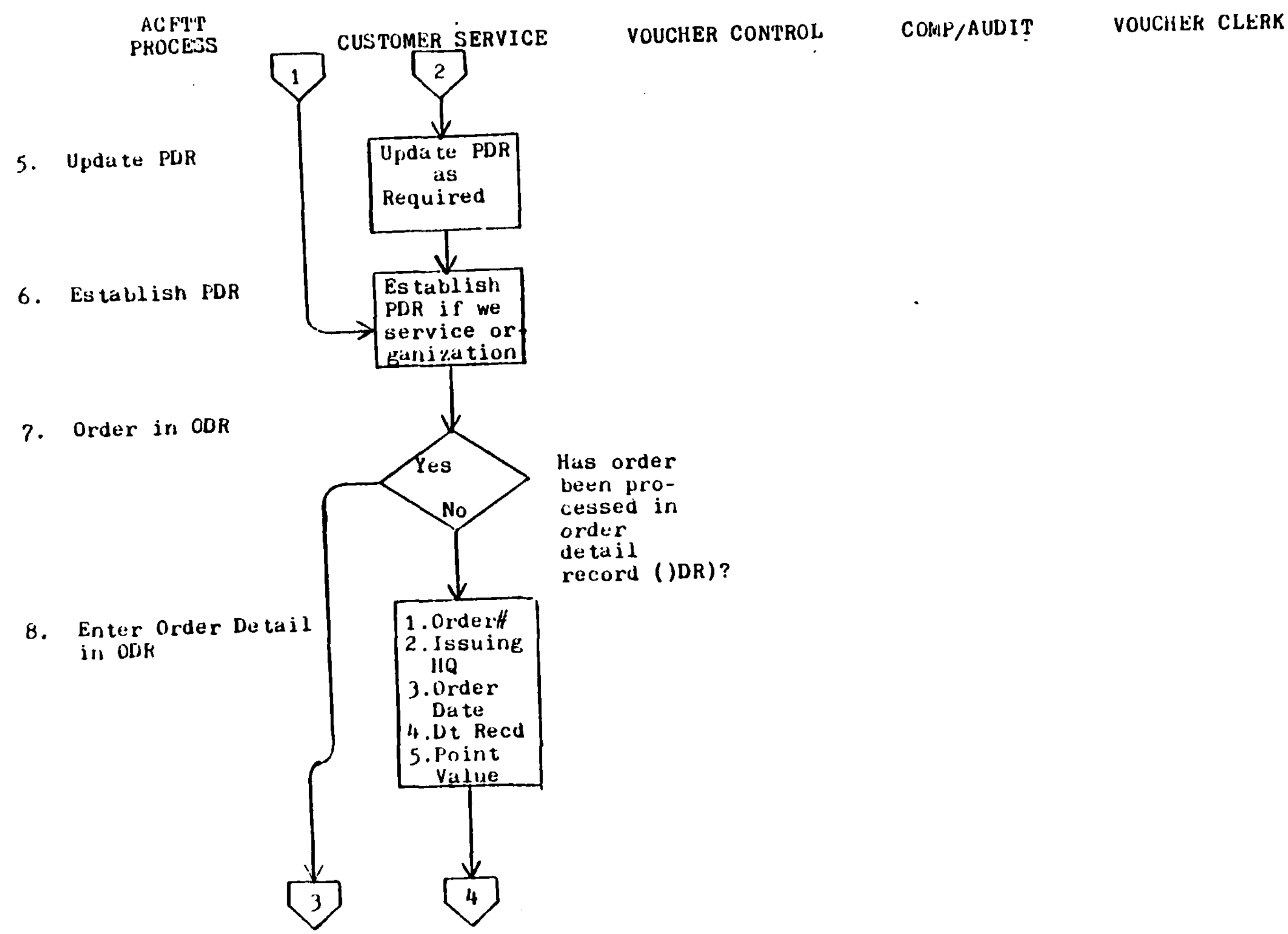
APPENDIX A

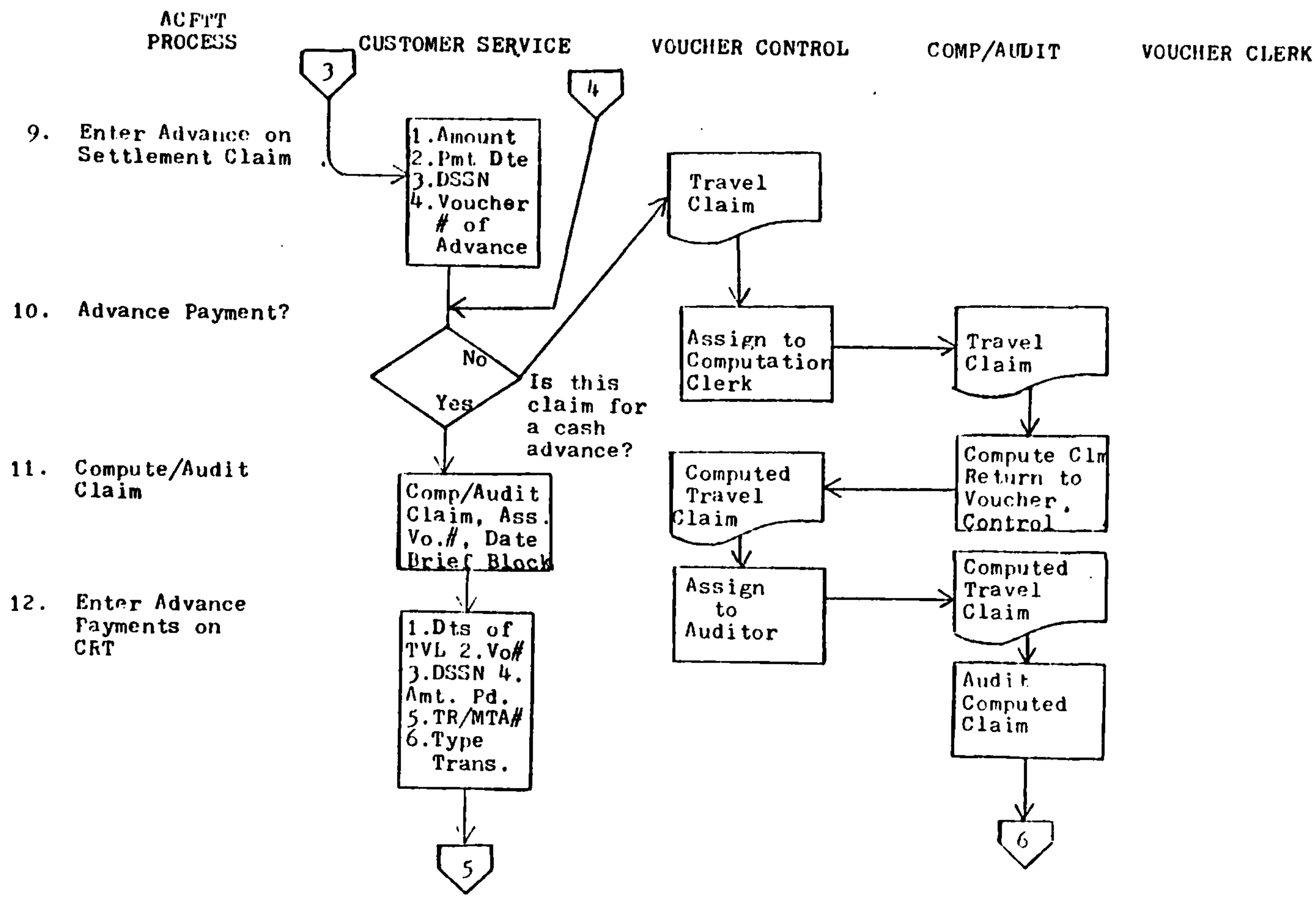
ACF FLOW CHART

ACFTT PROCESS	CUSTOMER SERVICE	VOUCHER CONTROL	COMP/AUDIT	VOUCHER CLERK

1. Receive Documents in
   1. Distribution
   2. Customer Service
   3. PCS In-Processing
2. Code Claim
3. Request Status
4. PDR on File?




ACFTT PROCESS
CUSTOMER SERVICE
VOUCHER CONTROL
COMP/AUDIT
VOUCHER CLERK
5. Update PDR
6. Establish PDR
7. Order in ODR
8. Enter Order Detail in ODR
1
2
Update PDR as Required
Establish PDR if we service organization
Yes
No
Has order been processed in order detail record ()DR)?
1.Order#
2.Issuing HQ
3.Order Date
4.Dt Recd
5.Point Value
3
4



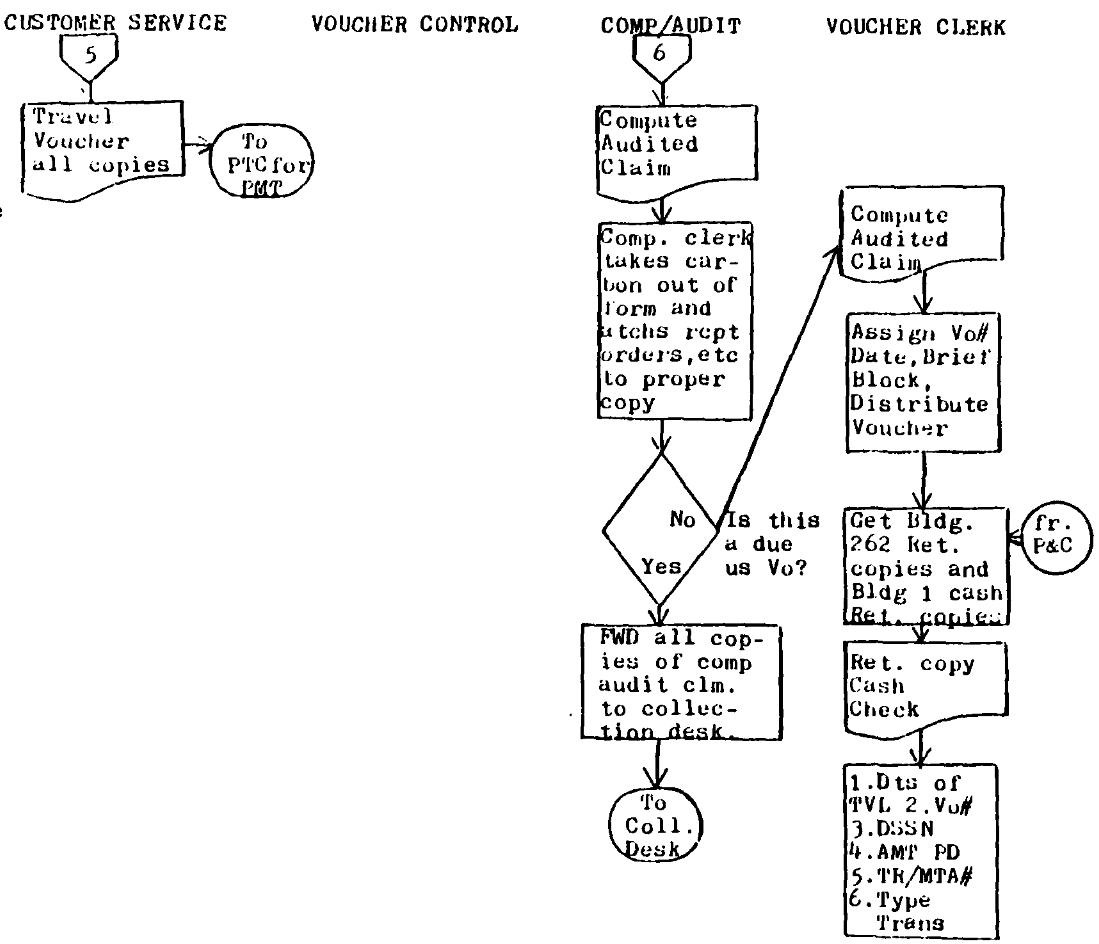
ACFTT PROCESS
CUSTOMER SERVICE
VOUCHER CONTROL
COMP/AUDIT
VOUCHER CLERK
9. Enter Advance on Settlement Claim
10. Advance Payment?
11. Compute/Audit Claim
12. Enter Advance Payments on CRT
3
4
1.Amount 2.Pmt Dte 3.DSSN 4.Voucher # of Advance
No
Yes
Is this claim for a cash advance?
Comp/Audit Claim, Ass. Vo.#, Date Brief Block
1.Dts of TVL 2.Vo# 3.DSSN 4. Amt. Pd. 5.TR/MTA# 6.Type Trans.
5
Travel Claim
Assign to Computation Clerk
Computed Travel Claim
Assign to Auditor
Travel Claim
Compute Clm Return to Voucher Control
Computed Travel Claim
Audit Computed Claim
6

ACFTT
PROCESS

13. Voucher & Distribute
Check Claims

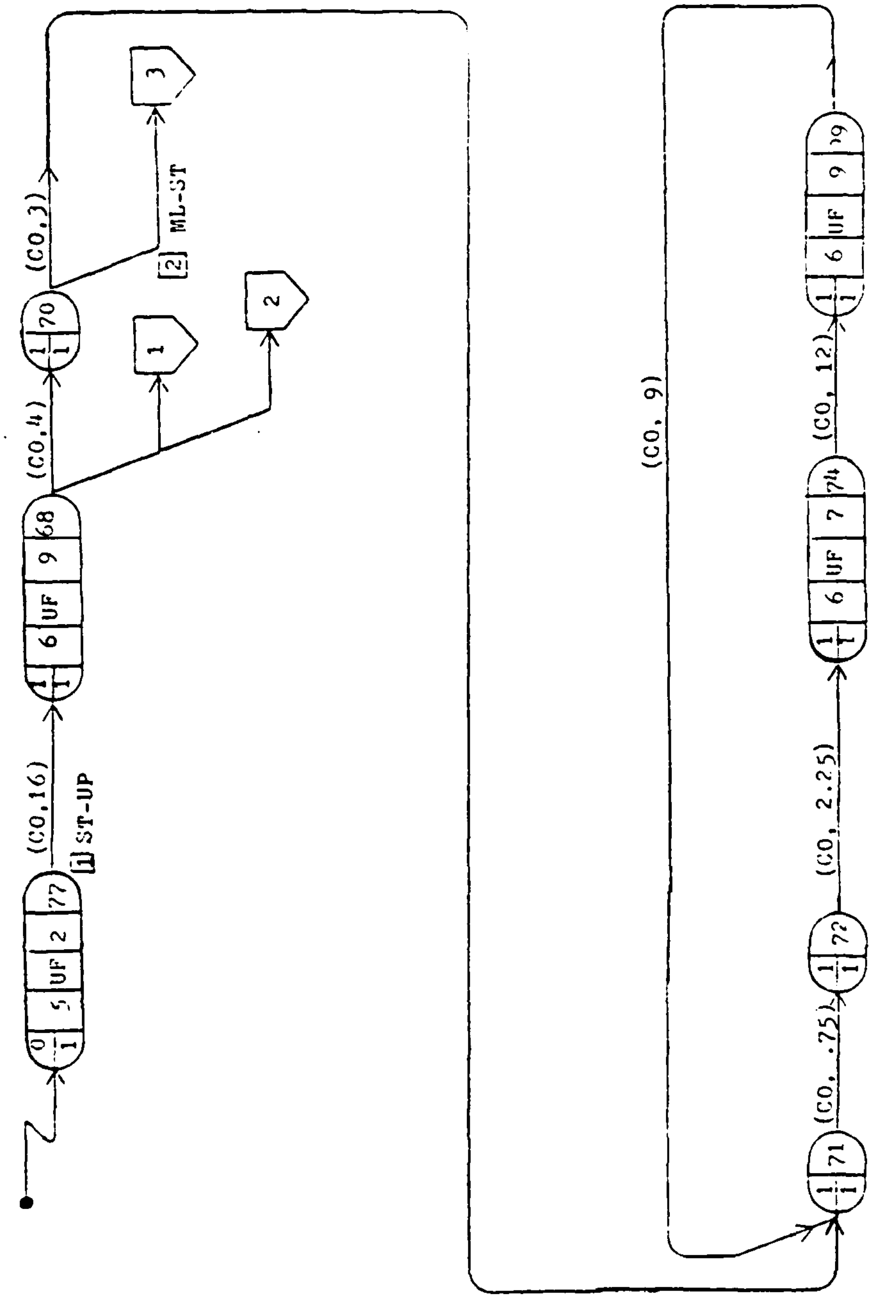
14. Get Advance Payment
Copies of P&C

15. Enter Cash & Check
PMT Data on ODR



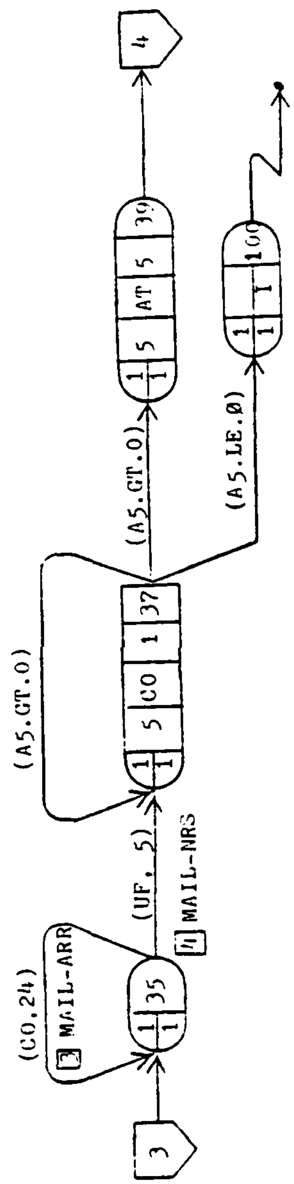
APPENDIX B

TIMING CIRCUIT


(CO,16)
1 ST-UP
(CO,4)
(CO,3)
2 ML-ST
(CO, 9)
(CO, .75)
(CO, 2.25)
(CO, 12)

APPENDIX C

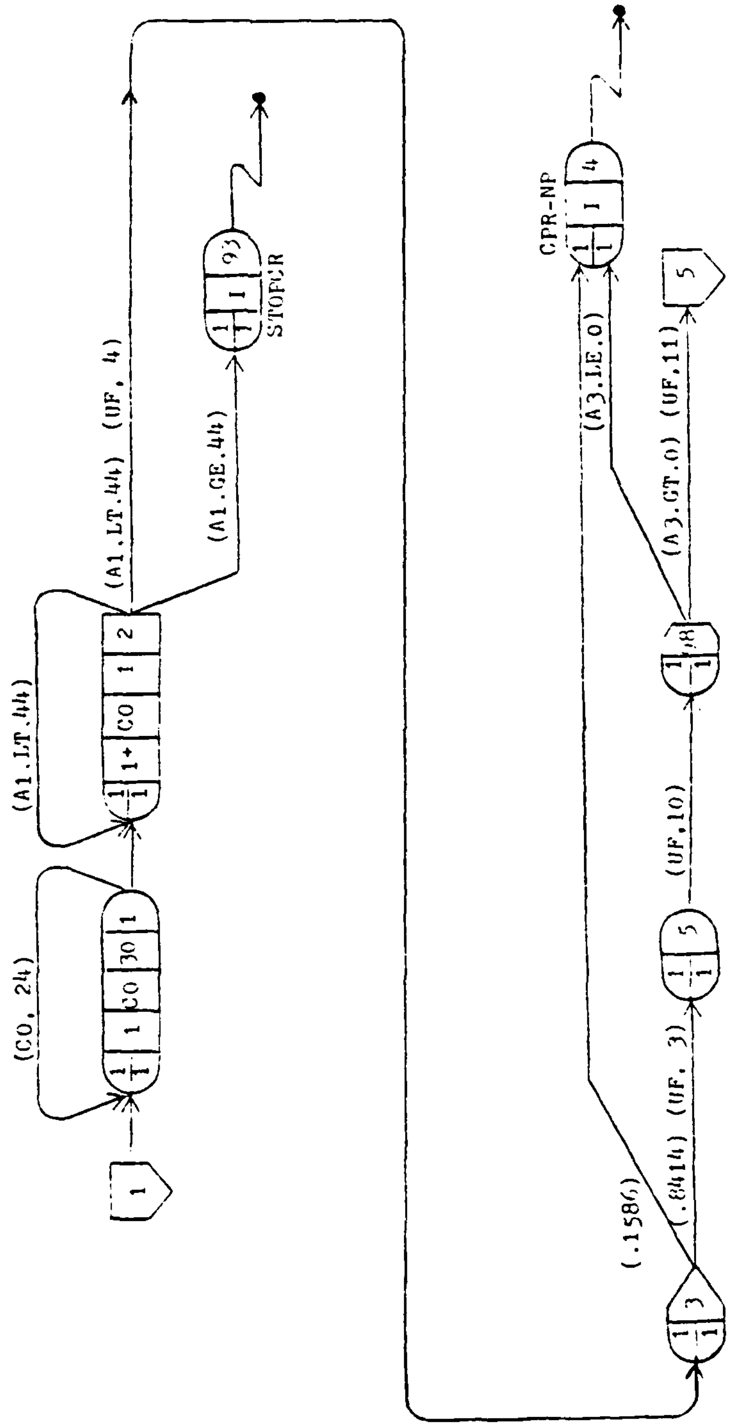
VOUCHER ARRIVALS



3
(CO.24)
3 MAIL-ARR
35
(UF, 5)
4 MAIL-NRS
(A5.GT.0)
5
CO
1
37
(A5.GT.0)
5
AT
5
39
4
(A5.LE.Ø)
I
100
STOPMAIL

APPENDIX D

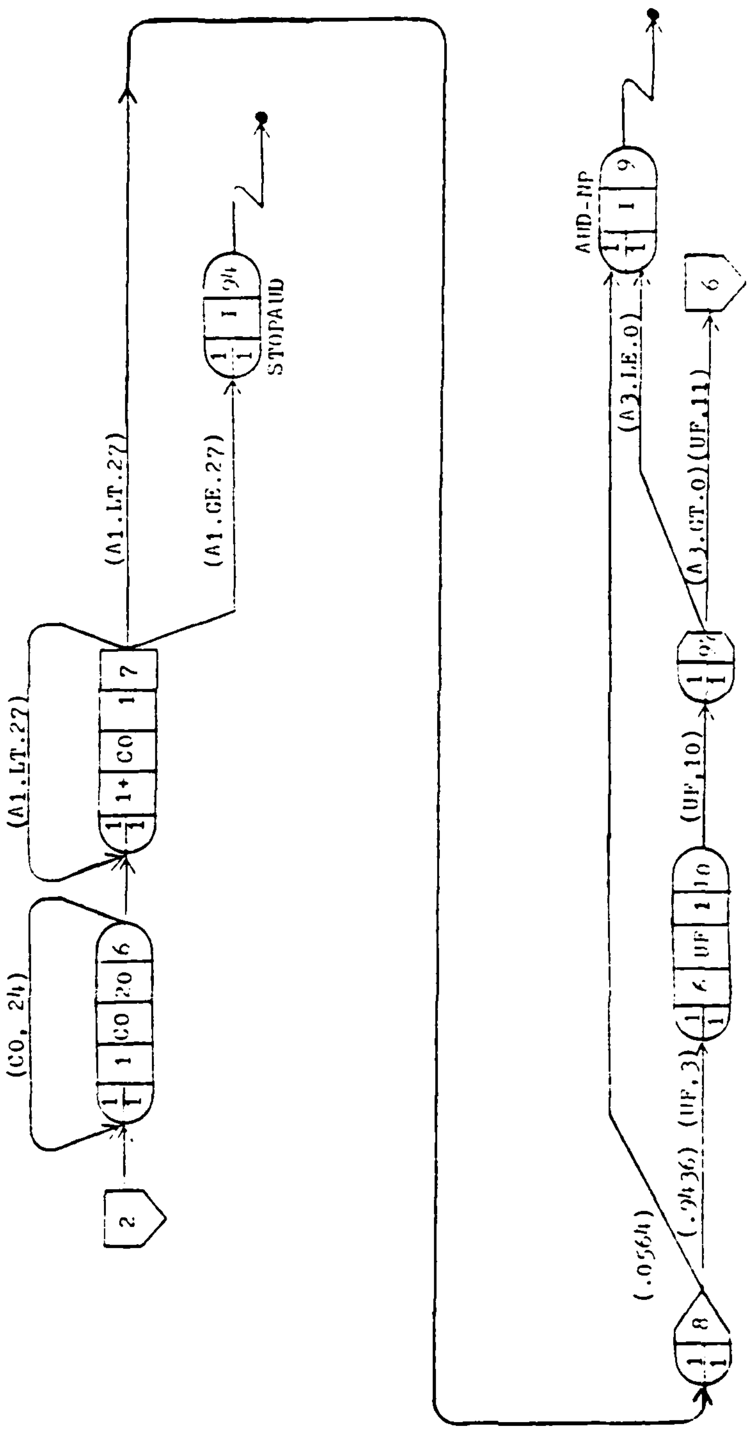
COMPUTOR ARRIVALS



(CO, 24)
(A1.LT.44)
(A1.LT.44) (UF, 4)
(A1.GE.44)
STOPCR
CPR-NP
(A3.LE.0)
(A3.GT.0) (UF,11)
(UF,10)
(.8414) (UF, 3)
(.1586)

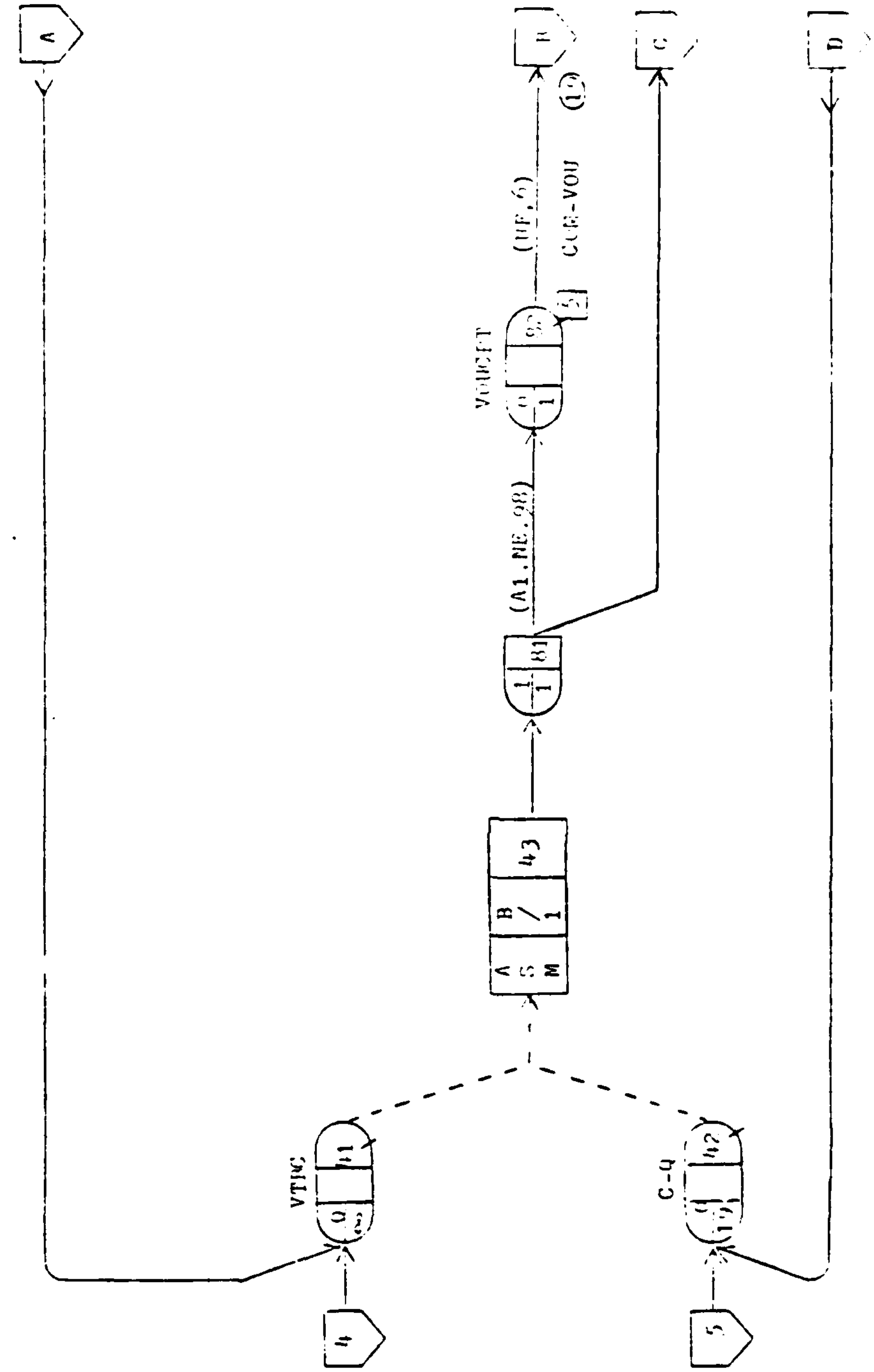
APPENDIX E

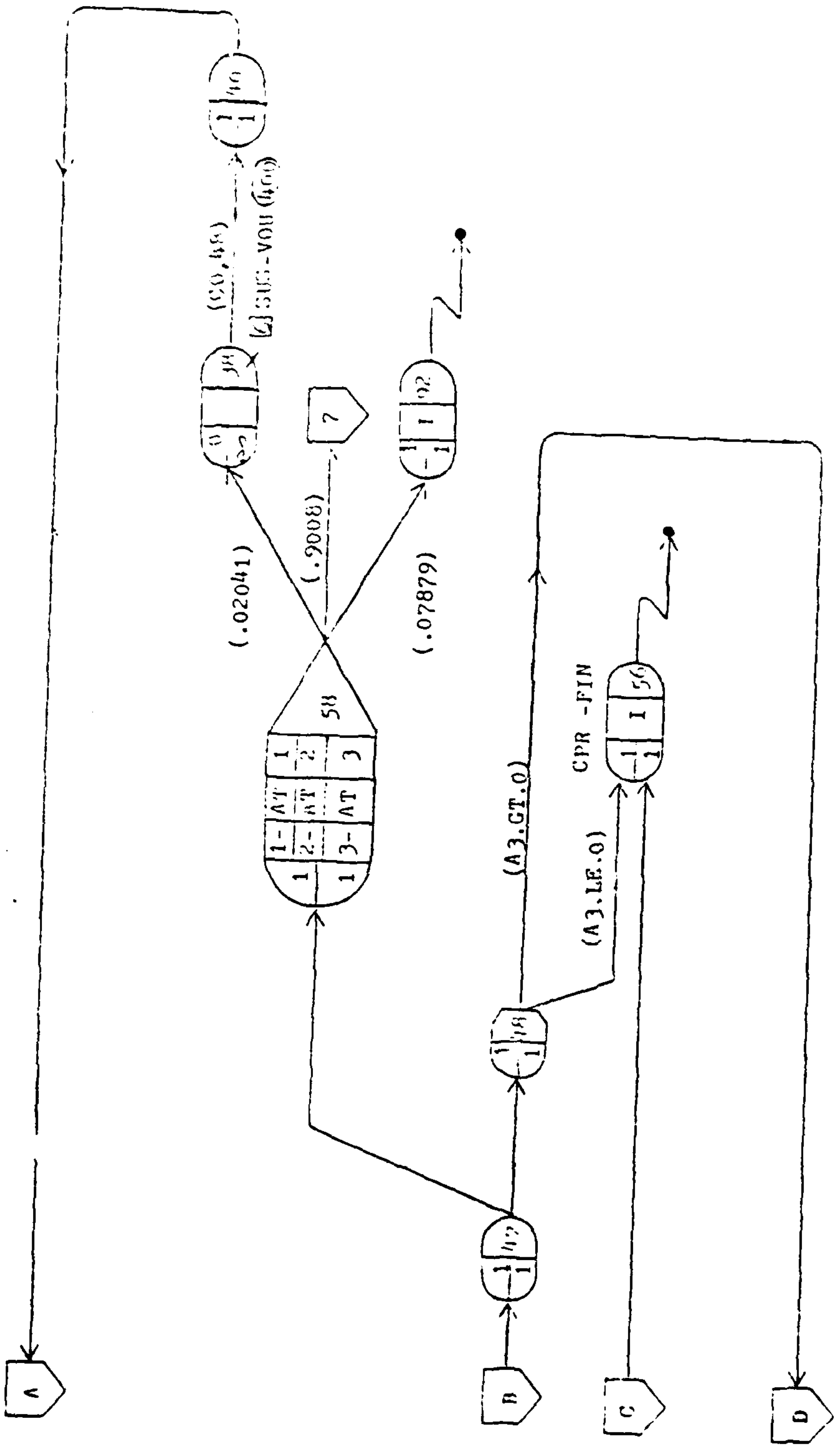
AUDITOR ARRIVALS


(CO, 24)
(A1.LT.27)
(A1.LT.27)
(A1.GE.27)
STOPAUD
AUD-NF
(A3.LE.0)
(A3.GT.0)
(UF,11)
(UF,10)
(UF,3)
(.9436)
(.0564)

APPENDIX F

COMPUTATION PROCESS

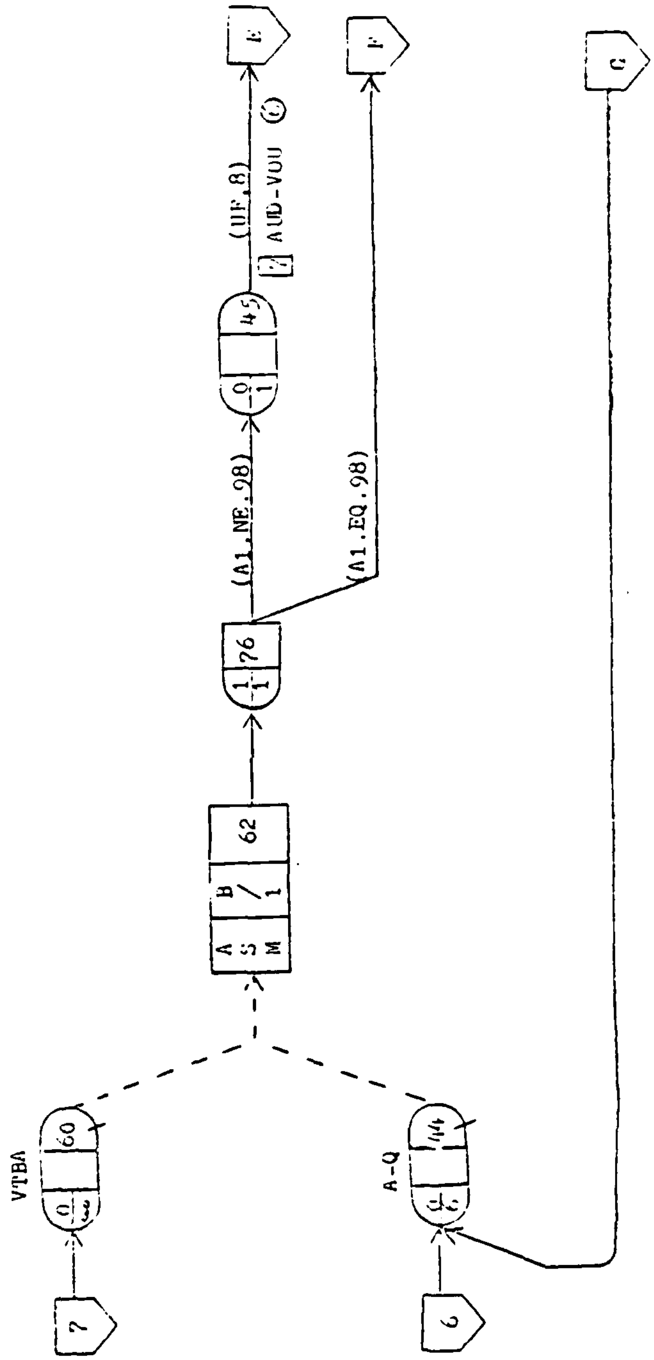

A
B
C
D
(UF,6)
CCE-VOU
(A1.NE.98)
81
A S M
B
1
43
VTIC
C-Q
4
5

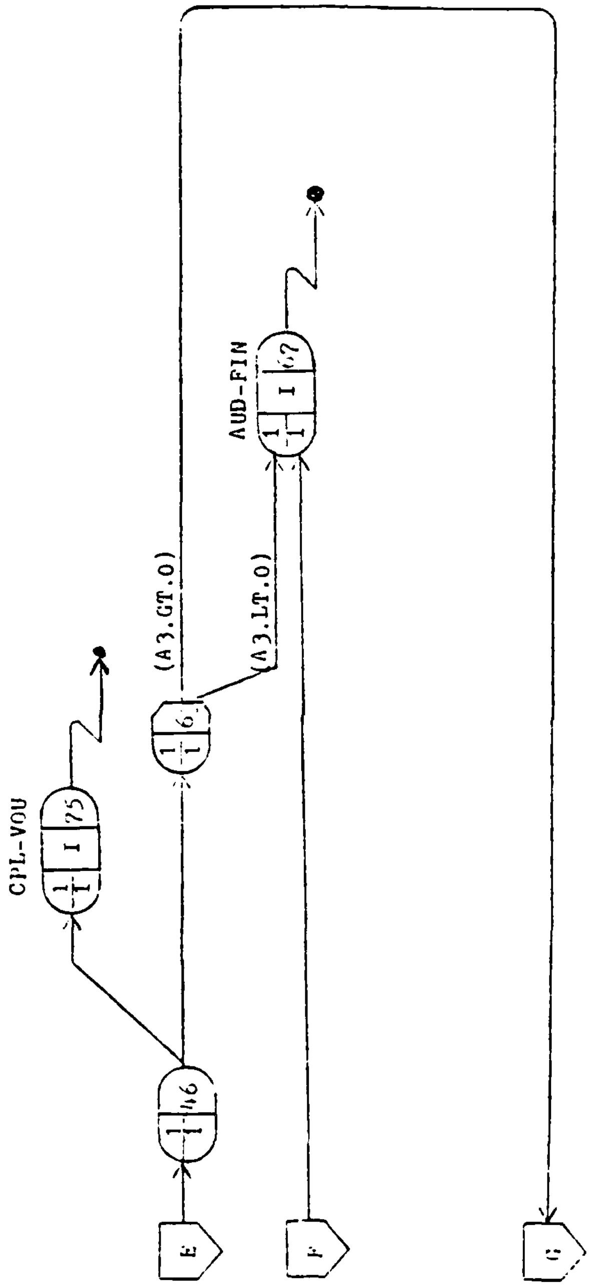


(.02041)
(.9008)
(.07879)
58
CPR -FIN
(A3.GT.0)
(A3.LE.0)
A
B
C
D

APPENDIX G

AUDIT PROCESS


E
F
G
(UF.8)
AUD-VOU
(A1.NE.98)
(A1.EQ.98)
45
76
A
S
M
B
1
62
VTBA
60
A-Q
7
6


CPL-VOU
AUD-FIN
(A3.GT.0)
(A3.LT.0)
E
F
G

APPENDIX H

Q-GERT

```
GEN,VEELL,THESIS,8,14,82,,9,999999,1574.5,15,F,,6*
SOU,77,,1*                                               BEGIN TIMING CIRCUIT.
VAS,77,5,UF,2*
ACT,77,68,,16.,1/ST-UP*
REG,68,,1*
VAS,68,6,UF,9*
ACT,68,1*
ACT,68,6*
ACT,68,70,,4.*
REG,70,,1*
ACT,70,35,,,2/ML-ST*
ACT,70,71,,3.*
REG,71,,1*
ACT,71,72,,.75*
REG,72,,1*
ACT,72,74,,2.25*
REG,74,,1*
VAS,74,6,UF,7*
ACT,74,99,,12.*
REG,99,,1*
VAS,99,6,UF,9*
ACT,99,71,,9.
                                                          BEGIN VOUCHER ARRIVALS.
REG,35,,1*
ACT,35,35,,24,3/MAIL-ARR*
ACT,35,37,UF,5,4/MAIL-NRS*
REG,37,,1,A*
VAS,37,5-,CO,1*
ACT,37,37,(8)1,A5.GT.0*
ACT,37,39,(8)1,A5.GT.0*
ACT,37,100,(8)1,A5.LE.0*
SIN,100/STOPMAIL,,1,.I*
REG,39,,1*
VAS,39,5-,AT,5*
ACT,39,41*
```

```
REG,1,,1*                              BEGIN COMPUTORS' ARRIVALS.
VAS,1,1,CO,30*
ACT,1,1,,24.*
ACT,1,2*
REG,2,,1,A*
VAS,2,1+,CO,1*
ACT,2,2,(8)1,A1.LT.44*
ACT,2,3,UF,4,(8)1,A1.LT.44*
ACT,2,93,(8)1,A1.GE.44*
REG,3,,1,P*
SIN,93/STOPCPR,,1,,I*
ACT,3,4,(8).1586*
ACT,3,5,UF,3,(8).8414*
SIN,4/CPR-NP,,1,,I*
REG,5,,1*
ACT,5,98,UF,10*
REG,98,,1,F*
ACT,98,4,(8)1,A3.LE.0.*
ACT,98,42,,,(8)1,A3.GT.0.0*
REG,6,,1*                              BEGIN AUDITORS' ARRIVALS.
VAS,6,1,CO,20*
ACT,6,6,,24.*
ACT,6,7*
REG,7,,1,A*
VAS,7,1+,CO,1*
ACT,7,7,(8)1,A1.LT.27*
ACT,7,8,(8)1,A1.LT.27*
ACT,7,94,(8)1,A1.GE.27*
REG,8,,1,P*
SIN,94/STOPAUD,,1,,I*
ACT,8,9,(8).0564*
ACT,8,10,UF,3,(8).9436*
SIN,9/AUD-NP,,1,,I*
REG,10,,1*
VAS,10,6,UF,1*
ACT,10,97,UF,10*
REG,97,,1,F*
ACT,97,9,(8)1.A3.LE.0.*
ACT,97,44,,,(8)1.A3.GT.0.*
```

```
QUE,41/VTBC,(10)43*                          BEGIN COMPUTE PROCESS.
QUE,42/C-Q,,19,(10)43*
SEL,43/C-V,ASM,,B/1,,41,42*
ACT,43,81*
REG,81,,1,A*
ACT,81,82,(8)1,A1.NE.98*
ACT,81,56,(8)1,A1.EQ.98*
SIN,56/CPR-FIN,,1,,I*
QUE,82/VOUCPT,,1*
ACT,82,47,UF,6,5/COM-VOU,19*
REG,47,,1*
ACT,47,58*
REG,58,,1,P*
VAS,58,1-,AT,1,2-,AT,2,3-,AT,3*
ACT,58,38,UF,11,(8).07879*
ACT,58,60,(8).9008*
ACT,58,92,(8).02041*
QUE,38/VOU-SUS*
SIN,92/RET-VOU,,1,,I*
ACT,38,40,CO,48,6/SUS-VOU,400*
REG,40,,1*
ACT,40,41*
ACT,47,48*
REG,48,,1,F*
ACT,48,42,(8)1,A3.GT.0.*
ACT,48,56,(8)1,A3.LE.0.0*
QUE,44/A-Q,,6,(10)62*                        BEGIN AUDIT PROCESS.
QUE,60/VTBA,(10)62*
SEL,62/AUD-VOU,ASM,,B/1,(7)44,60*
ACT,62,76*
REG,76,,1,A*
ACT,76,45,(8)1,A1.NE.98*
ACT,76,67,(8)1,A1.EQ.98*
QUE,45/VOUAUD,,1*
SIN,67/AUD-FIN,,1,,I*
ACT,45,46,UF,8,7/AUD-VOU,6*
REG,46,,1*
ACT,46,63*
ACT,46,75*
REG,63,,1,F*
SIN,75/CPL-VOC,,1,,I*
ACT,63,67,(8)1,A3.LE.0*
ACT,63,44,(8)1,A3.GT.0*
```

```
PAR,2,224.677,96.,498.,80.,10*          BEGIN PARAMETER CARDS.
PAR,10,476.846,148.,882.,188.903,10*
PAR,3,1.556,0.5,3.25,.906,3*
PAR,5,3.267,1.25,7.5,1.656,5*
PAR,21,3.893,0.25,7.0,1.632,7*
PAR,51,17.236,8.,44.,6.337,6*
PAR,81,1.732,.25,6.5,1.568,9*
PAR,22,2.401,0.5,6.25,1.811,7*
PAR,52,7.688,3.05,16.,2.73,6*
PAR,82,2.537,0.25,6.,1.713,9*
PAR,23,3.462,0.0,7.0,1.929,7*
PAR,53,9.748,3.14,26.53,3.984,6*
PAR,24,3.898,0.0,7.5,1.777,7*
PAR,54,9.382,3.53,21.,3.853,6*
PAR,84,2.039,.25,7.0,1.516,9*
PAR,25,4.463,1.0,7.5,1.734,7*
PAR,55,10.649,7.33,22.,3.212,6*
PAR,85,1.905,.25,7.5,1.896,9*
PAR,26,2.523,.5,7.5,1.809,7*
PAR,56,8.958,1.13,13.07,2.867,6*
PAR,31,2.413,0.5,7.75,2.098,9*
PAR,61,3.697,2.,5.4,.829,8*
PAR,32,4.241,0.5,7.75,1.984,9*
PAR,62,,4.,9.87,,8*
PAR,33,2.635,0.5,7.0,2.007,9*
PAR,63,6.479,3.5,11.16,2.545,8*
PAR,34,4.75,.75,8.0,1.998,9*
PAR,64,6.343,2.96,12.57,1.947,8*
PAR,35,2.417,0.5,7.0,1.772,9*
PAR,65,4.928,1.5,8.4,1.309,8*
PAR,36,2.545,0.5,6.5,1.633,9*
PAR,66,4.937,2.,11.56,1.811,8*
PAR,37,1.473,0.5,6.0,1.382,9*
PAR,67,4.564,3.,6.93,.806,8*
PAR,38,4.0,1.0,8.75,1.933,9*
PAR,68,5.5,3.08,10.,1.677,8*
PAR,39,5.333,0.75,7.5,1.711,9*
PAR,69,4.91,1.69,8.,1.569,8*
PAR,40,2.312,0.5,7.5,1.761,9*
PAR,70,4.674,2.46,8.33,1.256,8*
PAR,41,4.962,2.0,7.5,1.556,9*
PAR,71,4.006,1.86,8.94,1.288,8*
PAR,42,5.212,0.5,7.5,1.781,9*
PAR,72,4.618,2.89,12.,1.68,8*
PAR,43,5.159,1.0,9.5,1.947,9*
PAR,73,9.74,4.,19.11,3.719,8*
COL,1/CON-VOU,2/AUD-VOC*
FIN*
```

APPENDIX I

USER FUNCTIONS

```
C
C     UI INITIALIZES VARIABLES PASSED BETWEEN SUBROUTINES.
C
      SUBROUTINE UI
      REAL PTPRO,VHPRO,SAMP,WORK
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     +NRUN,NRUNS,NTC(500),PARAM(100,4),TBEG,TNOW/CT/WORK,
     +PTPRO,VHPRO/CV/SAMP
      WORK=0.0
      PTPRO = 0.0
      VHPRO=0.0
      SAMP=0.0
      CALL COLC(0)
      RETURN
      END
C
C     UF PERFORMS RANDOM SAMPLING AND OTHER
C     OPERATIONS BASED ON THE VALUE OF KEY.
C
      FUNCTION UF(KEY)
      REAL SAMP,CSAMP,ASAMP,AT1,NO,WORK,LO,AUDT,TIME,
     +ASG1,ASG2,SPEED,PTPRO,VHPRO,AUDNR,SPD
      INTEGER J,IC,IA,IS,K,I,ITCQ,ITAQ,ITVREM
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     +NRUN,NRUNS,NTC(500),PARAM(100,4),TBEG,TNOW/CT/WORK,
     +PTPRO,VHPRO/CV/SAMP
      DIMENSION ATT(6),ACSON(5),ACSONV(5),ACSTW(3),ACSTWV(3),
     +ACSTH(3),ACSTHV(3),ACSFO(2),ACSFOV(2),ACSFI(2),ACSFIV(2),
     +ACSSI(2),ACSSIV(2),AONC(2),ATWC(2),ATHA(2),ATHC(21),AFOA(2),
     +AFIA(2),ASIA(2),ASIC(5),AVAL(2),ATHCV(21),ASICV(5),ATWA(2),
     +CTON(2),CTTW(2),CTTH(2),CTFO(2),CTFI(2),CTSI(2),
     +CTSE(2),CTEI(2),CTNI(2),CTTE(2),CTEL(2),CTTL(2),
     +CVAL(2),CPT(2),APT(2),AFOC(2),AFIC(2),
     +ASP(4),ASPV(4),CTASGV(16),CTASG(16)
      DATA CSAMP,ASAMP,AUDNR,SPD/4*0.0/
```

```
      DATA ACSON/.881,.9048,.9286,.9762,1.0/
     +ACSONV/4.,4.15,4.5,6.,7.08/
     +ACSTW/.05,.95,1.0/ACSTWV/3.78,4.,6.91/ACSTH/.95122,.97561,
     +1.0/ACSTHV/4.,4.55,6./ACSFO/.9778,1.0/ACSFOV/4.,5.29/
     +ACSFI/.9787,1.0/ACSFIV/4.,8.55/ACSSI/.75,1.0/ACSSIV/4.,
     +11.86/ATHC/.3152,
     +.3667,.4834,.5667,.6,.6667,.7167,.7334,.7834,.8167,.8334,
     +.8501,.8668,.8835,.9002,.9169,.9336,.9503,.967,.9837,1.0/
     +ASIC/.9348,.9538,.9692,.9846,1.0/
     +AVAL/0.0,1.0/ATHCV/0.0,.25,.5,.75,1.0,1.25,
     +1.5,1.75,2.0,2.25,2.75,3.0,3.75,4.25,4.5,5.0,5.25,6.25,6.5,
     +7.25,7.5/ASICV/0.0,.5,1.5,5.0,5.25/
     +CVAL/0.0,1.0/
     +ATWA/.0217,1.0/ATHA/.038,1.0/AFOA/.1359,1.0/
     +AFIA/.087,1.0/ASIA/.5761,1.0/
     +CTON/0.0,1.0/CTTW/.3418,1.0/CTTH/.2686,1.0/
     +CTFO/.1406,1.0/CTFI/.0675,1.0/CTSI/.1041,1.0/
     +CTSE/.2320,1.0/CTEI/.1772,1.0/CTNI/.3966,1.0/
     +CTTE/.0126,1.0/CTEL/.3783,1.0/CTTL/.3235,1.0/
     +AONC/.3967,1.0/ATWC/.5598,1.0/AFOC/.1848,1.0/
     +AFIC/.1522,1.0/
     +CPT/.3297,1.0/APT/.3333,1.0/ASP/.833,.8886,.9442,
     +1.0/ASPV/8.,8.5,10.,10.5/CTASGV/36,31,23,40,33,
     +22,37,41,34,24,25,35,39,32,38,42/CTASG/
     +.087,.184,.252,.349,.5043,.5723,.6213,.6313,.6896,
     +.7386,.7870,.8160,.8450,.9320,.9610,1.0/
      DATA J,IC,IA,IS,K,I,ITCQ,ITAQ,ITVREM/9*0/
C
      GO TO(1,2,3,4,5,6,7,8,9,10,11),KEY
C
C     KEY = 1: SAMPLES THE INDIVIDUAL AUDITORS' COMPUTE AND
C              AUDIT PRODUCTIVE TIMES.  COMPARES THE TOTAL
C              TIME TO 4 HOURS (8/2) TO ENSURE NO OVERTIME.
C              INSERTS A COMPUTOR INTO THE COMPUTOR ARRIVAL
C              SYSTEM ONLY IF THE INDIVIDUAL AUDITOR HAS
C              COMPUTE TIME (ATTRIBUTE 2).  INSERTS THE
C              AUDIT PRODUCTIVE TIME INTO ATTRIBUTE 3.
```

```
C
1     UF=0.0
      AT1=GATRB(1)
      IF(AT1.EQ.ASG1)RETURN
      IF(AT1.EQ.ASG2)RETURN
      J=AT1
      I=J-20
      GO TO(21,22,23,24,25,26),I
21    SAMP=NO(J)
      SAMP=SAMP/2
      CALL CONVERT
      AUDT=SAMP
      SAMP=DPROB(AONC,AVAL,2,9)
      IF(SAMP.GT.0.0)THEN
         SAMP=LO(81)
         SAMP=SAMP/2
         CALL CONVERT
         TIME=AUDT+SAMP
         IF(TIME-4.0)310,310,21
310      ATT(1)=44.
         ATT(2)=GATRB(2)
         ATT(3)=SAMP
         CALL PTIN(98,0.0,TNOW,ATT)
      END IF
      GO TO 27
22    SAMP=DPROB(ATWA,AVAL,2,7)
      IF(SAMP.GT.0.0)THEN
         SAMP=LO(J)
         SAMP=(8.0-SAMP)
         SAMP=SAMP/2
         CALL CONVERT
      END IF
      AUDT=SAMP
      SAMP=DPROB(ATWC,AVAL,2,9)
      IF(SAMP.GT.0.0)THEN
         SAMP=NO(82)
         SAMP=SAMP/2
         CALL CONVERT
         TIME=AUDT+SAMP
         IF(TIME-4.0)320,320,22
```

```
 320      ATT(1)=45.
          ATT(2)=GATRB(2)
          ATT(3)=SAMP
          CALL PTIN(98,0.0,TNOW,ATT)
       END IF
       GO TO 27
 23    SAMP=DPROB(ATHA,AVAL,2,7)
       IF(SAMP.GT.0.0)THEN
          SAMP=NO(J)
          SAMP=(8.-SAMP)
          SAMP=SAMP/2
          CALL CONVERT
       END IF
       AUDT=SAMP
       SAMP=DPROB(ATHC,ATHCV,21,9)
       IF(SAMP.GT.0.0)THEN
          SAMP=SAMP/2
          CALL CONVERT
          TIME=SAMP+AUDT
          IF(TIME-4.0)330,330,23
 330      ATT(1)=46.
          ATT(2)=GATRB(2)
          ATT(3)=SAMP
          CALL PTIN(98,0.0,TNOW,ATT)
       END IF
       GO TO 27
 24    SAMP=DPROB(AFOA,AVAL,2,7)
       IF(SAMP.GT.0.0)THEN
          SAMP=LO(J)
          SAMP=(8.-SAMP)
          SAMP=SAMP/2
          CALL CONVERT
       END IF
       AUDT=SAMP
       SAMP=DPROB(AFOC,AVAL,2,9)
       IF(SAMP.GT.0.0)THEN
          SAMP=LO(84)
          SAMP=SAMP/2
          CALL CONVERT
          TIME=AUDT+SAMP
          IF(TIME-4.0)340.340,24
```

```
 340     ATT(1)=47.
         ATT(2)=GATRB(2)
         ATT(3)=SAMP
         CALL PTIN(98,0.0,TNOW,ATT)
      END IF
      GO TO 27
 25   SAMP=DPROB(AFIA,AVAL,2,7)
      IF(SAMP.GT.0.0)THEN
         SAMP=NO(J)
         SAMP=SAMP/2
         CALL CONVERT
      END IF
      AUDT=SAMP
      SAMP=DPROB(AFIC,AVAL,2,9)
      IF(SAMP.GT.0.0)THEN
         SAMP=LO(85)
         SAMP=SAMP/2
         CALL CONVERT
         TIME=SAMP+AUDT
         IF(TIME-4.0)350,350,25
 350     ATT(1)=48.
         ATT(2)=GATRB(2)
         ATT(3)=SAMP
         CALL PTIN(98,0.0,TNOW,ATT)
      END IF
      GO TO 27
 26   SAMP=DPROB(ASIA,AVAL,2,7)
      IF(SAMP.GT.0.0)THEN
         SAMP=LO(J)
         SAMP=SAMP/2
         CALL CONVERT
      END IF
      AUDT=SAMP
      SAMP=DPROB(ASIC,ASICV,5,9)
      IF(SAMP.GT.0.0)THEN
         SAMP=SAMP/2
         CALL CONVERT
         TIME=SAMP+AUDT
         IF(TIME-4.0)360,360,26
```

```
360     ATT(1)=49.
        ATT(2)=GATRB(2)
        ATT(3)=SAMP
        CALL PTIN(98,0.0,TNOW,ATT)
      END IF
27    CALL PATRB(0.0,2)
      CALL PATRB(AUDT,3)
      ATT(1)=0.0
      ATT(2)=0.0
      ATT(3)=0.0
      RETURN
C
C     KEY = 2: ESTABLISHES LOGNORMAL PARAMETERS AND
C              INSERTS REMAINING VOUCHERS INTO APPROPRIATE
C              QUEUES FOR START UP CONDITIONS.
C
2     IF(NRUN.NE.1)GO TO 20
      CALL CPLO(2)
      CALL CPLO(3)
      CALL CPLO(5)
      CALL CPLO(10)
      CALL CPLO(22)
      CALL CPLO(24)
      CALL CPLO(26)
      CALL CPLO(33)
      CALL CPLO(35)
      CALL CPLO(36)
      CALL CPLO(37)
      CALL CPLO(40)
      CALL CPLO(51)
      CALL CPLO(52)
      CALL CPLO(53)
      CALL CPLO(54)
      CALL CPLO(55)
      CALL CPLO(56)
      CALL CPLO(63)
      CALL CPLO(64)
      CALL CPLO(66)
      CALL CPLO(67)
      CALL CPLO(68)
      CALL CPLO(70)
      CALL CPLO(71)
      CALL CPLO(72)
      CALL CPLO(81)
      CALL CPLO(84)
      CALL CPLO(85)
```

```
20    SAMP=397
      SAMP=SAMP/2
      CSAMP=.8083*SAMP
      IC=INT(CSAMP)
      ASAMP=.1917*SAMP
      IA=INT(ASAMP)
      SAMP=.00403*CSAMP
      IS=INT(SAMP)
      DO 110,K=1,IC
        ATT(5)=0.0
        CALL PTIN(41,0.0,TNOW,ATT)
110   CONTINUE
      DO 120,K=1,IA
        ATT(5)=0.0
        CALL PTIN(60,0.0,TNOW,ATT)
120   CONTINUE
      DO 130,K=1,IS
         ATT(5)=0.0
         CALL PTIN(38,0.0,TNOW,ATT)
130   CONTINUE
      UF=0.0
      RETURN
C
C     KEY = 3: SAMPLES AND INSERTS (1) AUDIT PROCESSING
C              SPEEDS INTO ATTRIBUTE 4 AND (2) COMPUTE
C              PROCESSING SPEEDS INTO ATTRIBUTE 2.
C
3     AT1=GATRB(1)
      J=AT1+30.
      IF(AT1-26)30,28,160
30    SAMP = LO(J)
      GO TO 29
28    SAMP = LO(J)
29    CALL PATRB(SAMP,4)
      I=J-50
      GO TO (121,122,123,124,125,126),I
121   SAMP=DPROB(ACSON,ACSONV,5,8)
      GO TO 127
```

```
  122 SAMP=DPROB(ACSTW,ACSTWV,3,8)
      GO TO 127
  123 SAMP=DPROB(ACSTH,ACSTHV,3,8)
      GO TO 127
  124 SAMP=DPROB(ACSFO,ACSFOV,2,8)
      GO TO 127
  125 SAMP=DPROB(ACSFI,ACSFIV,2,8)
      GO TO 127
  126 SAMP=DPROB(ACSSI,ACSSIV,2,8)
      GO TO 127
  160 IF(J.EQ.61.OR.J.EQ.65.OR.J.EQ.69.OR.J.EQ.73)SAMP=NO(J)
      IF(J.EQ.62)SAMP=UN(J)
      IF(J.EQ.63.OR.J.EQ.64.OR.J.EQ.66.OR.J.EQ.67.OR.J.EQ.68
     +.OR.J.EQ.70.OR.J.EQ.71.OR.J.EQ.72)SAMP=LO(J)
  127 CALL PATRB(SAMP,2)
      UF=0.0
      RETURN
C
C     KEY = 4: SAMPLES AND INSERTS COMPUTORS' PRODUCTIVE
C              TIME INTO ATTRIBUTE 3.
C
    4 AT1=GATRB(1)
      J=AT1
      I=J-30
      GO TO(31,32,33,34,35,36,37,38,39,40,41,42,48),I
   31 SAMP=DPROB(CTON,CVAL,2,9)
      IF(SAMP)44,49,44
   32 SAMP=DPROB(CTTW,CVAL,2,9)
      IF(SAMP)45,49,45
   33 SAMP=DPROB(CTTH,CVAL,2,9)
      IF(SAMP)44,49,44
   34 SAMP=DPROB(CTFO,CVAL,2,9)
      IF(SAMP)45,49,45
   35 SAMP=DPROB(CTFI,CVAL,2,9)
      IF(SAMP)44,49,44
   36 SAMP=DPROB(CTSI,CVAL,2,9)
      IF(SAMP)44,49,44
   37 SAMP=DPROB(CTSE,CVAL,2,9)
      IF(SAMP)44,49,44
```

```
38    SAMP=DPROB(CTEI,CVAL,2,9)
      IF(SAMP)45,49,45
39    SAMP=DPROB(CTNI,CVAL,2,9)
      IF(SAMP)45,49,45
40    SAMP=DPROB(CTTE,CVAL,2,9)
      IF(SAMP)44,49,44
41    SAMP=DPROB(CTEL,CVAL,2,9)
      IF(SAMP)45,49,45
42    SAMP=DPROB(CTTL,CVAL,2,9)
      IF(SAMP)45,49,45
44    SAMP=LO(J)
      SAMP=(8.-SAMP)
      GO TO 49
45    SAMP=NO(J)
      GO TO 49
46    SAMP=NO(J)
      SAMP=(8.0-SAMP)
      GO TO 49
47    SAMP=UN(J)
      GO TO 49
48    SAMP=NO(J)
49    SAMP=SAMP/2
      CALL CONVERT
      CALL PATRB(SAMP,3)
      UF=0.0
      RETURN
C
C     KEY = 5: SAMPLES AND INSERTS VOUCHER ARRIVALS
C              USING ATTRIBUTE 5 AS A COUNT VARIABLE.
C
5     SAMP=LO(2)
      J = INT(SAMP)
      SAMP = J
      SAMP=SAMP/2
      CALL PATRB(SAMP,5)
      UF=0.0
      RETURN
C
```

```
C     KEY = 6: CALLS SUBROUTINE COMPUTE TO DETERMINE
C              COMPUTATION PROCESS DURATION.
C
6     CALL COMPUTE
      CALL COL(WORK,1)
      UF=WORK
      RETURN
C
C     KEY= 7:  DETERMINES IF ANY PERSONNEL REMAIN
C              AWAITINT WORK AT DAY'S END.  IF SO,
C              INSERTS DUMMY VOUCHERS TO CLEAR THE
C              PERSONNEL FROM THE SYSTEM.
C
7     IF(XNINQ(41).LT.XNINQ(42))THEN
        I=XNINQ(42)-XNINQ(41)
        DO 230,K=1,I
          ATT(1)=98.
          CALL PTIN(41,0.0,TNOW,ATT)
          ATT(1)=0.0
230     CONTINUE
      END IF
      IF(XNINQ(60).LT.XNINQ(44))THEN
         I=XNINQ(44)-XNINQ(60)_
         DO 240,K=1,I
            ATT(1)=98.
            CALL PTIN(60,0.0,TNOW,ATT)
            ATT(1)=0.0
240      CONTINUE
      END IF
      UF=0.0
      RETURN
C
C     KEY = 8: CALLS SUBROUTINE AUDIT TO
C              DETERMINE AUDIT PROCESS DURATION
C
8     CALL AUDIT
      CALL COL(WORK,2)
      UF=WORK
      RETURN
C
```

```
C      KEY = 9: WRITES TO A SEPERATE FILE THE POINTS PROCESSED
C               VOUCHERS PROCESSED, NR. IN THE COMPUTE AND
C               AUDIT QUEUES, AND THE TIME REMAINING IN BOTH
C               VOUCHER QUEUES.  MAKES THE PERSONNEL COUNTER
C               ASSIGNMENTS FOR THE NEXT DAY.
C
9      ITCQ = XNINQ(41)
       ITAQ = XNINQ(60)
       I=ISTUS(38,76)
       IF(I)210,220,220
210    I = 400
220    ITAQ=ITAQ+I
       ITVREM = ITCQ + ITAQ
       WRITE(11,500) NRUN,NTC(58),PTPRO,VHPRO,ITCQ,ITAQ,ITVREM
500    FORMAT(' ',2X,I5,3X,I4,3X,2(F8.2,3X),3(I4,3X))
       PTPRO = 0.0
       VHPRO = 0.0
       I = 0
       ASG1=DPROB(CTASG,CTASGV,16,4)
61     ASG2=DPROB(CTASG,CTASGV,16,4)
       IF(ASG1-ASG2)60,61,62
60     IF(30.-ASG2)63,63,61
62     IF(30.-ASG1)63,63,61
63     UF=0.0
       RETURN
C
C      KEY = 10: DETERMINES COUNTER PERSONNEL PROCESSING
C                SPEEDS AND PRODUCTIVE TIMES AND INSERTS
C                THEM INTO ATTRIBUTES 2 AND 3 RESPECTIVELY
C
```

```
10    UF=0.0
      AT1=GATRB(1)
      IF(AT1.NE.ASG1)THEN
         IF(AT1.NE.ASG2)RETURN
      END IF
      IF(AT1.GE.30.)THEN
         SAMP=DPROB(CPT,CVAL,2,5)
         IF(SAMP.GT.0.0)THEN
            SAMP=LO(5)
            CALL PATRB(4.,2)
         END IF
         SAMP=SAMP/2
         CALL CONVERT
         CALL PATRB(SAMP,3)
      ELSE
         SAMP=DPROB(APT,CVAL,2,3)
         IF(SAMP.GT.0.0)THEN
            SAMP=LO(3)
            SPEED=DPROB(ASP,ASPV,4,2)
            CALL PATRB(SPEED,4)
         END IF
         SAMP=SAMP/2
         CALL CONVERT
         CALL PATRB(SAMP,3)
      END IF
      RETURN
C
C     KEY = 11: PULLS SUSPENDED VOUCHERS AND DELAYS
C               PROCESSING BY 48 HOURS
C
11    UF=0.0
      CALL STAGO(34,48,0.0.0,ATT)
      CALL PTIN(60,0.0,TNOW,ATT)
      RETURN
      END
C
```

```
C
C     COMPUTE DETERMINES COMPUTATION PROCESS DURATION
C
      SUBROUTINE COMPUTE
      REAL VOUCHER,SPD,WORK,PRDTME
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     +NRUN,NRUNS,NTC(500),PARAM(100,4),TBEG,TNOW/CT/WORK,
     +PTPRO,VHPRO/CV/SAMP
      DIMENSION VOU(6),VOUV(6)
      DATA VOU/.18,.8742,.9837,.9932,.9991,1.0/
     +VOUV/0.5,1.0,2.0,3.0,4.0,5.0/
      SPD=GATRB(2)
      PRDTME=GATRB(3)
      VOUCHER = DPROB(VOU,VOUV,6,1)
      WORK=VOUCHER/SPD
      PRDTME=PRDTME-WORK
      CALL PATRB(PRDTME,3)
      RETURN
      END
C
C
C     AUDIT DETERMINES AUDIT PROCESS DURATION.
C
      SUBROUTINE AUDIT
      REAL SPD,WORK,PRDTME,VOUCHER,PTPRO,VHPRO
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     +NRUN,NRUNS,NTC(500),PARAM(100,4),TBEG,TNOW/CT/WORK,
     +PTPRO,VHPRO/CV/SAMP
      DIMENSION VOU(6),VOUV(6)
      DATA VOU/.18,.8742,.9837,.9932,.9991,1.0/
     +VOUV/0.5,1.0,2.0,3.0,4.0,5.0/
      SPD=GATRB(4)
      PRDTME=GATRB(3)
      VOUCHER = DPROB(VOU,VOUV,6,1)
      WORK=VOUCHER/SPD
      PRDTME = PRDTME - WORK
      IF(WORK.EQ.0.0)GO TO 100
      PTPRO = PTPRO + VOUCHER
      VHPRO = VHPRO + 1.
  100 CALL PATRB(PRDTME,3)
      RETURN
      END
C
```

```
C
C     CONVERT CONVERTS ALL PRODUCTIVE TIMES
C     INTO NEXT QUARTER HOUR INCREMENT.
C
      SUBROUTINE CONVERT
      REAL SAMP,X,Y
      INTEGER I,K
      COMMON/CV/SAMP
      I=SAMP
      X=I
      DO 50 K=1,4
          Y=X+.25
          IF(SAMP.GT.X)THEN
              IF(SAMP.LE.Y)SAMP=Y
          END  IF
          X=Y
50    CONTINUE
      RETURN
      END
C
C
C     UO PRINTS OUT AVERAGE DURATION FOR
C     THE COMPUTE AND AUDIT PROCESSES.
C
      SUBROUTINE UO
      COMMON/QVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     +NRUN,NRUNS,NTC(500),PARAM(100,4),TBEG,TNOW/CT/WORK,
     +PTPRO,VHPRO/CV/SAMP
      CALL COLP(0)
      RETURN
      END
```

APPENDIX J

VARIABLE LIST

VARIABLE	REAL	INTEGER	DEFINITION
ACSFI	X		Compute speed probabilities for auditor 25
ACSFIV	X		Auditor 25 compute speeds
ACSFO	X		Compute speed probabilities for auditor 24
ACSFOV	X		Auditor 24 compute speeds
ACSON	X		Compute speed probabilities for auditor 21
ACSONV	X		Auditor 21 compute speeds
ACSSI	X		Compute speed probabilities for auditor 26
ACSSIV	X		Auditor 26 compute speeds
ACSTH	X		Compute speed probabilities for auditor 23
ACSTHV	X		Auditor 23 compute speeds
ACSTW	X		Compute speed probabilities for auditor 22
ACSTWV	X		Auditor 22 compute speeds
AFIA	X		Probability of auditor 25 having productive time to audit

VARIABLE	REAL	INTEGER	DEFINITION
AFIC	X		Probability of auditor 25 having productive time to compute
AFOA	X		Probability of auditor 24 having productive time to audit
AFOC	X		Probability of auditor 24 having productive time to audit
AONC	X		Probability of auditor 21 having productive time to compute
APT	X		Probability of auditor assigned to counter being productive
ASAMP	X		Number of vouchers placed in *to-audit queue* at *simulation* start
ASG1	X		Processor selected for counter duty
ASG2	X		Processor selected for counter duty
ASIA	X		Probability of auditor 26 having productive time to audit
ASIC	X		Probabilities of auditor 26's compute productive times
ASICV	X		Compute productive times for auditor 26
ASP	X		Counter auditor processing time probabilities

VARIABLE	REAL	INTEGER	DEFINITION
ASPV	X		Counter auditor processing times
AT1	X		Attribute 1, identifies processor as computor or auditor
ATHA	X		Probability of auditor 23 having productive audit time
ATHC	X		Probabilities for auditor 23's productive compute times
ATHCV	X		Compute productive times for auditor 23
ATT	X		Attribute
ATWA	X		Probability of auditor 22 having productive audit time
ATWC	X		Probability of auditor 22 having productive compute time
AUDNR	X		Auditor number
AUDT	X		Auditor productive time
AVAL	X		DPROB value for determining whether an auditor is productive or not
CPT	X		Probability of computor assigned to counter being productive
CSAMP	X		Number of vouchers place in to-compute queue at simulation start

VARIABLE	REAL	INTEGER	DEFINITION
CTASG	X		Counter selection probabilities
CTASGV	X		Personnel available for counter duty
CTEI	X		Probability of computor 38 being productive
CTEL	X		Probability of computor 41 being productive
CTFI	X		Probability of computor 35 being productive
CTFO	X		Probability of computor 34 being productive
CTNI	X		Probability of computor 39 being productive
CTON	X		Probability of computor 31 being productive
CTSE	X		Probability of computor 37 being productive
CTSI	X		Probability of computor 36 being productive
CTTE	X		Probability of computor 40 being productive
CTTH	X		Probability of computor 33 being productive

VARIABLE	REAL	INTEGER	DEFINITION
CTTL	X		Probability of computor 42 being productive
CTTW	X		Probability of computor 32 being productive
CVAL		X	Used to determine whether personnel are productive or not
I		X	Utility variable
IA		X	Used to place vouchers in to-audit queue at simulation start
IC		X	Used to place vouchers in to-compute queue at simulation start
IS		X	Used to place vouchers in suspense at simulation start
ITAQ		X	Number of vouchers in to-audit queue
ITCQ		X	Number of vouchers in to-compute queue
ITVREM		X	Total vouchers in to-audit and to-compute queues
J		X	Value of attribute 1
K		X	Used to control DO statements
LO	X		Lognormal distribution sample

VARIABLE	REAL	INTEGER	DEFINITION
NO	X		Normal distribution sample
PRDTME	X		Productive time
PTPRO	X		Points processed
SAMP	X		Random sampling using parameters from PAR inputs
SPD	X		Processor compute or audit work speed
TIME	X		Auditor total audit and compute time
UN	X		Uniform distribution sample
VHPRO	X		Vouchers processed
VOU	X		Probabilities of voucher point values
VOUCHER	X		Selected point value of voucher
VOUV	X		Different point values of vouchers
WORK	X		Time to process voucher
X	X		Used with variable Y to round productive time to next quarter-hour increment
Y	X		Used with variable X to round productive time to next quarter-hour increment

APPENDIX K

CONFIDENCE INTERVALS

PARAMETER CARD	UPPER BOUNDARY	LOWER BOUNDARY
21	3.490	4.296
51	15.761	18.801
81	1.258	2.206
22	1.913	2.889
52	6.953	8.423
82**	1.735	3.339
23	2.938	3.986
53	8.665	10.831
24	3.395	4.401
54	8.292	10.472
84	1.623	2.455
25	3.987	4.939
55	9.768	10.472
85	1.404	2.406
26**	1.721	3.325
56**	7.687	10.229
31	2.355	2.471
61	3.465	3.929
32**	3.456	5.026
62	UNIFORM DISTRIBUTION	
33**	1.787	3.483
63**	5.404	7.554
34	4.138	5.362
64	5.747	6.939
35	1.921	2.913
65	4.558	5.298
36	2.033	3.058
66	4.369	5.505
37	1.045	1.901
67	4.304	4.824

PARAMETER CARD*	UPPER BOUNDARY	LOWER BOUNDARY
38	3.454	4.585
68	4.993	6.007
39	4.721	5.945
69	4.349	5.472
40	1.792	2.832
70	4.303	5.045
41	4.431	5.493
71	3.567	4.446
42	4.604	5.820
72	4.045	5.191
43	4.644	5.674
73	8.757	10.723

*ATTRIBUTES
2X: Auditors' Productive Times
5X: Audit Speed
8X: Auditors' Compute Speeds
3X-4X: Computors' Productive Times
6X-7X: Compute Speed

**SMALL SAMPLE SIZE

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